[11(4) oct 1977]

In Press
J. Fish Biol.

APPROACHES TO THE ANALYSIS OF ENERGETIC COSTS OF INTRASPECIFIC COMPETITION FOR SPACE BY RAINBOW TROUT (*SALMO GAIRDNERI*)

Hiram W. Li

and

Robert W. Brocksen[1]

Division of Wildlife and Fisheries Biology
University of California, Davis

---

[1] Present address: Division of Environmental Sciences
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

[57: pp373-376, 77]

The Metabolic Cost of Food Utilization
and Ammonia Production by Juvenile
Macrobrachium rosenbergii (Crustacea:Palaemonidae)

In Press Comp. Biochem Physiol.
Part A
Comparative Physiology

S. G. Nelson and A. W. Knight
Department of Land, Air and Water Resources
Water Science and Engineering Section
University of California
Davis, California 95616

and

H. W. Li
Division of Wildlife and Fisheries
University of California
Davis, California 95616

[58A: pp 319-327, 1977]

In Press

Comp Biochem & Physiol.

Calorie, Carbon, and Nitrogen Metabolism of Juvenile *Macrobrachium rosenbergii* (De Man) (Crustacea, Palaemonidae) with Regard to Trophic Position

Stephen Glen Nelson[1]

Hiram W. Li[2]

and

Allen W. Knight[1]

University of California

Davis, California 95616

---

[1] Department of Land, Air and Water Resources.

[2] Department of Wildlife and Fisheries Biology.

U of Cal Water Science & Engineering Papers #4507 P.52-54 1978

The Effects of Temperature and Salinity on the Metabolic Rate of Juvenile *Macrobrachium rosenbergii* (Crustacea:Palaemonidae)

In Press (NO) Comp. Biochem Physiol

S. G. Nelson[1], D. A. Armstrong[1], A. W. Knight[1] and H. W. Li[2]

University of California

Davis, California 95616

U.S.A.

---

[1] Department of Land, Air and Water Resources, Water Science and Engineering Section.

[2] Department of Animal Physiology.

[1978]

CURRENT STATUS OF CUTTHROAT TROUT SUBSPECIES IN THE WESTERN BONNEVILLE BASIN

Terry J. Hickman[1] and Donald A. Duff[2]

ABSTRACT.— Recent discoveries of native cutthroat trout populations in desert mountain ranges on the western fringe of the Bonneville Basin have prompted intensified management efforts by state and federal agencies. Analysis of Snake Valley cutthroat specimens in Trout Creek, Deep Creek Mountain Range, Utah, indicate this is a pure strain of the trout which once inhabited Pleistocene Lake Bonneville and which was thought to be extinct in Utah. The Snake Valley cutthroat is similar to *Salmo clarki utah* of the eastern Bonneville Basin; however, electrophoretic and morphomeristic analysis show unique genetic differences brought about by long-term isolation (8,000 years) from the remainder of the Bonneville Basin cutthroat. This cutthroat is a common ancestor to several other limited cutthroat populations within the basin in Nevada. In May 1977 the BLM withdrew from mineral entry about 27,000 acres within the Deep Creek Mountains for protection of this salmonid cutthroat and other unique resources on the range. Results of 1977 stream surveys on the Pilot Peak Mountain Range, Utah, indicate the presence of the threatened Lahontan cutthroat, *Salmo clarki henshawi,* in one isolated stream.

The ancient Pleistocene Lake Bonneville in the Great Basin once supported a cutthroat trout, native to the Snake Valley area of Utah-Nevada, which abounded in the area's several streams upon the lake's decline (Hickman 1977). Because of deteriorating habitat the cutthroat population rapidly diminished in the twentieth century to a point where it was believed to be extinct within its native range (Behnke 1976a) (Fig. 1).

In 1953 Ted Frantz, Nevada Fish and Game Department, discovered a cutthroat trout population in Pine Creek on Mt. Wheeler, Nevada (Frantz and King 1958). Samples were sent to Dr. Robert Miller, who indicated they represented pure cutthroat trout. But Dr. Miller was unable to assign them to any described subspecies (letter from Dr. Miller to F. Dodge, 26 May 1971). Though it was assumed this cutthroat was introduced from Trout Creek drainage of the Snake Valley area (Miller and Alcorn 1946), this seems unlikely when one considers that there were streams closer to Pine Creek which probably contained cutthroat trout (Lehman, Baker, Snake, and Hendrys creeks). Behnke (1976a) indicates the most logical origin of the Pine Creek cutthroat was from Lehman Creek (Mt. Wheeler tributary of the Snake Valley region) via the Osceola Ditch, constructed as a pioneer waterway.

During 1953 the Nevada Fish and Game Department introduced 44 fish from Pine Creek into Hampton Creek, Nevada. A second transplant of 54 cutthroat from Pine Creek was made into Goshute Creek, Nevada, in 1960. The Nevada Fish and Game Department, assuming these were Utah cutthroat, *Salmo clarki utah,* closed these streams to fishing and listed *S.c. utah* as an endangered species in Nevada. Mr. Frank Dodge, Nevada Fish and Game Department, in 1972 found a population of cutthroat trout in the headwaters of Hendrys Creek (Mt. Moriah tributary of the Snake Valley region) which resembled those found in Pine Creek. Following this, several unsuccessful attempts were made by the Nevada Fish and Game Department to locate additional pure populations of cutthroat trout in the Snake Valley area of Utah and Nevada.

In 1973 the BLM (Utah) began stream habitat surveys in the Deep Creek Moun-

---

[1] Department of Fishery & Wildlife Biology, Colorado State University, Fort Collins, Colorado.

[2] Fisheries Biologist, U.S. Bureau of Land Management, Utah State Office, University Club Building, 136 South Temple, Salt Lake City, Utah 84111.

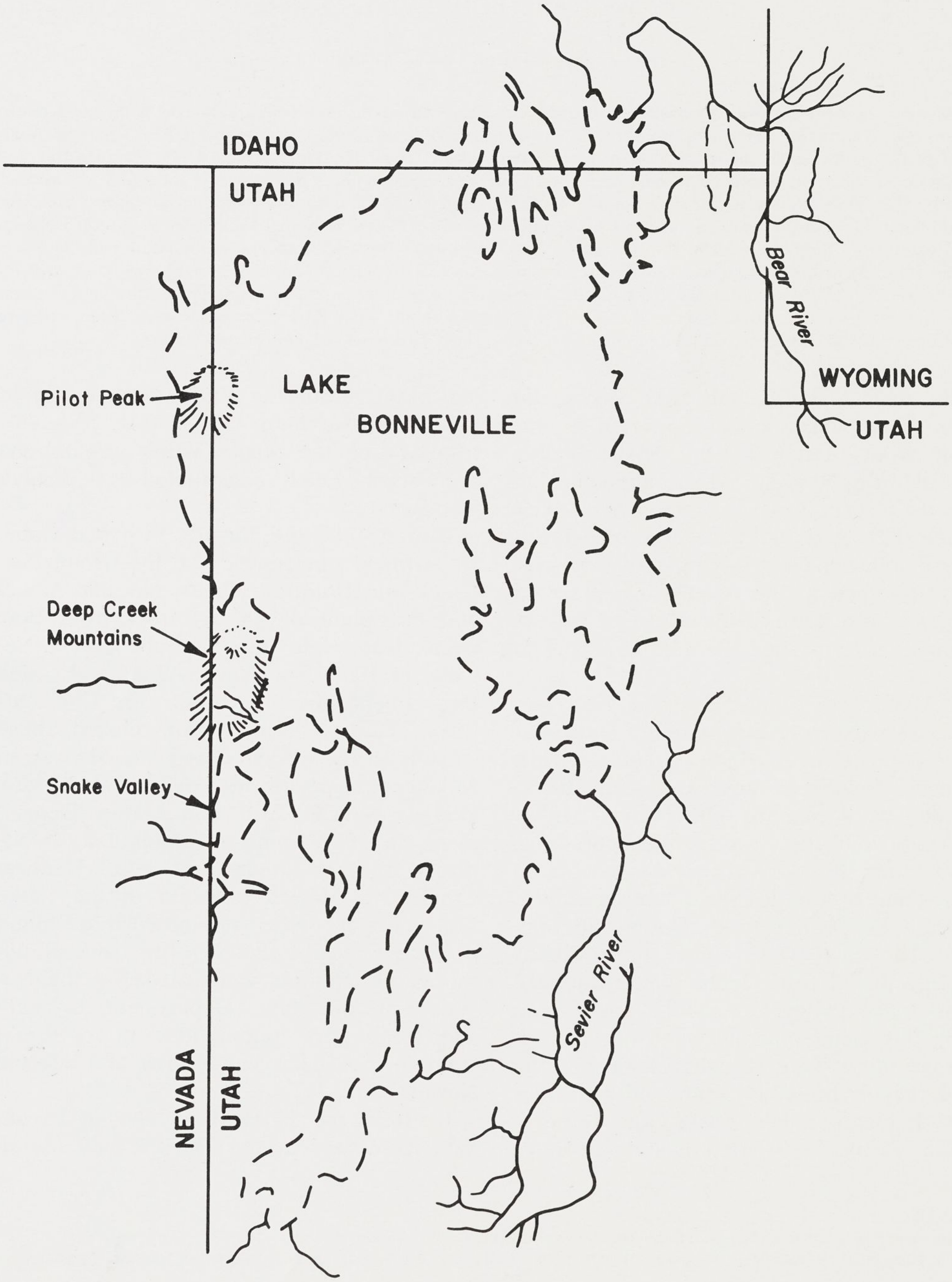


Fig 1. Area map location showing the western Bonneville Basin area.

FISH HABITAT CHANGES IN SUMMIT CREEK, IDAHO, AFTER FENCING THE RIPARIAN AREA

Charles Keller, Loren Anderson, and Paul Tappel[1]

U.S. Bureau of Land Management, Salmon, Idaho

From Grazing/Riparian
Forum:Denver, Colo.
11/3&4/1978
Published:T.U.-3/79

INTRODUCTION

The lost streams of Idaho originate in the mountains west of the Continental Divide and flow south to the desert lands of the Snake River Plains. There they sink into lava beds before reaching the Snake River; hence the name "lost streams." These streams, the Big Lost River, Little Lost River, and Birch Creek have apparently been isolated since the early Pleistocene (Stearns, Crandall, and Steward 1938). The three Lost River systems probably contribute to the "Thousand Springs" aquifer complex near Hagerman, Idaho.

Summit Creek is a primary tributary to the Little Lost River in east-central Idaho. After arising from a small group of springs on a state section of land, it flows through 2½ miles of public land before entering private land (Fig. 1).

Summit Creek flows through a broad, semi-arid, high-elevation sagebrush basin about 40 miles north of Howe, Idaho (Fig. 2). The basin is flanked on the east by the Lemhi Mountain Range and on the west by the Donkey Hills and Lost River Mountain Range. Pronghorn antelope, deer, sage grouse, and numerous species of non-game birds and mammals frequent the area. The area receives about 15 inches of precipitation each year. Snow accounts for 5 inches of the annual precipitation. Summit Creek receives little overland runoff from the surrounding land.

Most of Summit Creek originates at Iron Springs, which moderates streamflows and water temperatures. The basic productivity of Summit Creek is closely related to its relatively constant flow and temperature. Streamflows measured 0.5 mile below Iron Springs were the same in August 1977 and August 1978 (9.4 cfs), even though 1977 was an extremely low runoff year in much of Idaho. Streamflows measured at various points along the stream in 1978 ranged from 9.4 to 10.5 cfs.

Water temperatures near the springs remained between 49° F and 55° F from January 10, 1978 to May 10,

---

[1] Present Address: Humboldt State University, Arcata, California 95521.

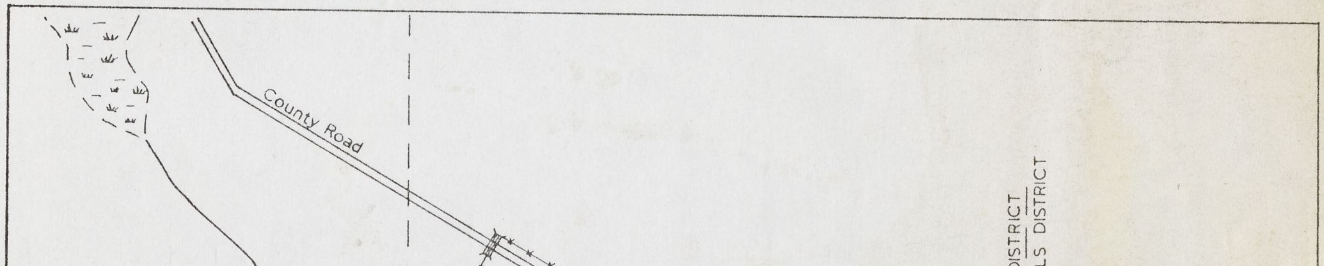


Figure 1. Summit Creek study area.

1978. During the same time, stream temperatures 2 miles below the springs fluctuated between 33° F and 60° F. Figure 3 illustrates the relatively wide temperature range encountered where the county road crosses Summit Creek, compared to the moderate temperature regime found near the Iron Springs outlet.

According to a survey by Hubbs and Miller (1948), cutthroat trout, Dolly Varden, and sculpin were the original fish present in Summit Creek. These fish represented a partial relict of upper Snake River fauna prior to the lava flows.

Idaho Department of Fish and Game Biologists believe that the upper few miles of Summit Creek furnish most of the spawning habitat for the entire Little Lost River and that it is a major wintering area for fish escaping the harsh winter environment lower in the drainage. Because of Summit Creek's natural productivity, several attempts have been made to maximize fish production in the stream.

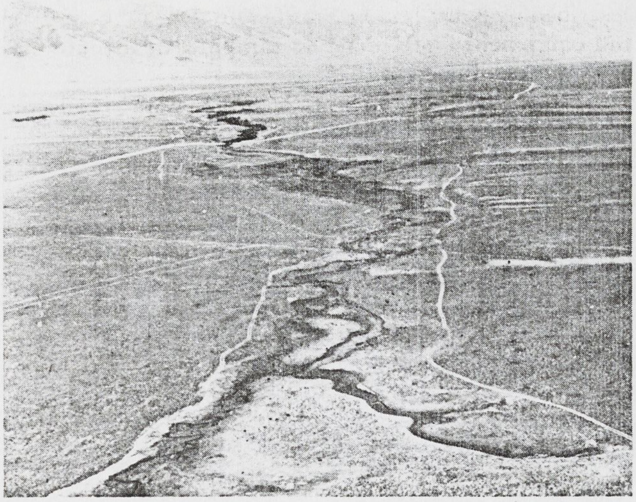


Figure 2. Aerial view of Summit Creek study area. Iron Springs is in lower right corner.

In 1968, Idaho Fish and Game personnel constructed an experimental trash catcher in upper Summit Creek. Subsequent electrofishing revealed that trout congregated in the vicinity of the structure (Jeppson 1971, personal communication).[2] Nine additional trash-catcher-type structures were installed by Idaho Fish and Game during 1971. Placement of these structures was on state and public land, approximately 0.25-0.75 miles downstream of Iron Springs. In addition, 12 old bridge timbers and planks were installed as water deflectors and artificial cover in an effort to enhance fish habitat.

Supplemental stocking of Summit Creek by Idaho Fish and Game was started in 1941 and continued through 1977. No fish were planted in 1978, so this study would not be influenced by artificial stocking. Observations by Bureau of Land Management (BLM) personnel indicated that most fishermen harvest hatchery stock and catches included very few wild fish.

Historically, deer, elk, antelope, bighorn sheep, and large herds of buffalo used the riparian zone of Summit Creek prior to the introduction of domestic livestock in the late 1800's. Cattle and sheep have been the primary grazers for the last 100 years. Wild and domestic horses also utilized the stream, but for a shorter period.

Streams such as Summit Creek which flow through deep soils and grassy meadows can be significantly impacted by livestock grazing. Armour (1977) summarized livestock impacts on rangeland streams, such as those occurring on Summit Creek:

---

[2] Paul Jeppson, Idaho Fish and Game, Idaho Falls, Idaho.

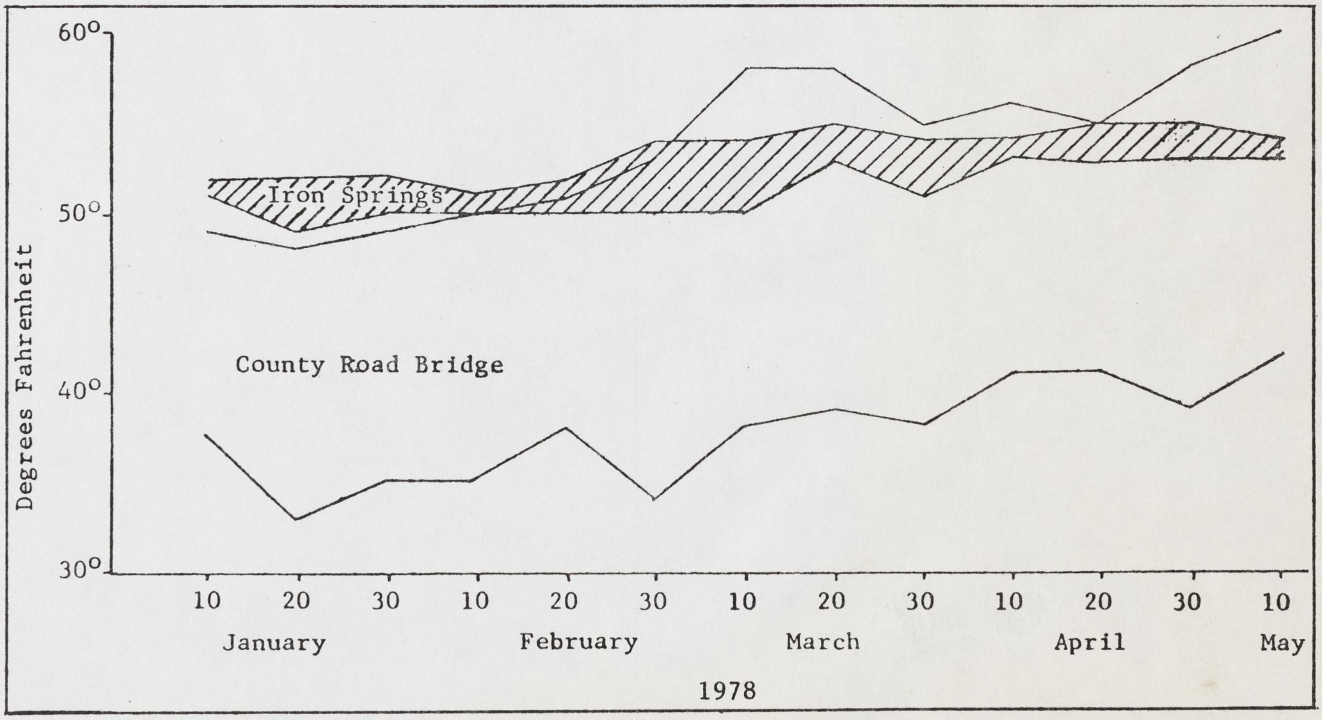


Figure 3. Ten-day temperature extremes recorded at Summit Creek thermograph stations.

"Livestock can alter the quality of stream habitat by damaging banks and decreasing the density of streamside vegetation. Bank damage, besides contributing to erosion and alteration of channels, can eliminate important trout habitat associated with banks. When streamside vegetation is cropped unacceptably, erosion and sedimentation are promoted. If shading is decreased, water temperatures can elevate to levels unsuitable for trout. Sedimentation can lessen trout reproductive success and the production of aquatic insects which are the predominant food base."

Excluding livestock from damaged stream areas to allow recovery of the streamside vegetation and bank stabilization is a proven management technique to improve trout habitat. Successful streambank fencing projects have been documented in Nebraska (Van Velson 1977); Oregon (Winegar 1977); Utah (Duff 1978); Wisconsin (White and Brynildson 1967); and elsewhere.

In an effort to protect fish habitat and the riparian environment, the Salmon District, BLM, fenced about 2 miles of Summit Creek after the 1975 grazing season. The project was completed with full cooperation of the livestock grazing permittee. Since 1975, changes in the riparian and stream environments have been documented both inside and outside the fenced area. In 1978, the study was expanded to include fish population sampling in both fenced (ungrazed) and unfenced (grazed) portions of Summit Creek.

Because of existing fence locations, it was more economical and facilitated better livestock distribution to "tie-in" to existing fences rather than fence parallel to the stream channel (Fig. 1). Fence construction was such that antelope and deer continue to use the project area. Three water gaps were constructed to provide livestock watering areas in both pastures. The entire exclosure (302.3 acres) contains 235.2 acres (77.8%) of sagebrush-grass, 45.1 acres (19.9%) of meadow, 16.0 acres (5.3%) of riparian/aquatic habitat, and 6.0 acres (2.0%) of county road.

METHODS

Eleven permanent stations were established along Summit Creek in 1976 so stream habitat changes could be monitored (Fig. 1). Stream habitat was resurveyed in 1978; stream width, average water depth, pool class, aquatic plants, bank cover, streambank stability, and degree of ungulate damage were compared to 1976 conditions (Tables 1, 2, and 3). Three new stations were established in 1978 immediately below the exclosure for future monitoring (Fig. 1).

In 1976, photographs were taken of each station plus additional points along the stream. Photographs were taken at the same location and at the same time of year in 1977 and 1978 to document changes in the aquatic and riparian zone.

Because a visual stream survey was used to quantify habitat changes, the data presented cannot be analyzed with rigorous statistical methods; however, for management purposes, correlating the photographs with the measured and/or observed habitat changes adequately describes what has occurred on Summit Creek since livestock were excluded from the sections of the riparian area.

TABLE 1. Characteristics of Summit Creek electrofishing stations, Summer 1978[a]

Station	Average width (ft.)	Average depth (ft.)	Streamflow (cfs)	Number of pools	Surface acres
1F-1[b]	12.9	0.8	9.4	5	.059
1F-2[c]	7.6	0.8	10.5	5	.035
S-1[d]	10.9	0.8	10.0	5	.050
S-2[e]	12.1	1.0	9.4	6	.056

[a] Refer to Figure 1 for sampling locations.
[b] Grazed/brush.
[c] Grazed/sagebrush-grass.
[d] Ungrazed/brush.
[e] Ungrazed/sagebrush-grass.

Summit Creek trout population densities were estimated in the summer of 1978, using the two-catch method described by Seber and LeCren (1976). Due to manpower and equipment limitations, no sampling of fish populations was conducted in 1976.

Four 200-foot stream sections were randomly selected; Stations S-1 and S-2 were within the Salmon District's fenced stream area and Stations 1F-1 and 1F-2 were downstream in grazed stream sections administered by the Idaho Falls District, BLM (Fig. 1). Stations S-1 (ungrazed) and 1F-1 (grazed) were representative of brushy stream sections. Stations S-2 (ungrazed) and 1F-2 (grazed) were both in exposed sagebrush-grass stream sections. Physical parameters of the four electrofishing stations sampled are listed in Table 1.

RESULTS AND DISCUSSION

Quantified changes observed within the fenced area from 1976 to 1978 are shown in Table 2. All features measured have improved during the 2-year period. Habitat conditions outside of the exclosure have remained unchanged or have improved slightly (Table 3). Water depth at Station 10 (grazed) has shown a slight improvement since 1976, although the increase is apparently due to the accumulation of additional debris on an unmaintained trash catcher, which has increased both depth and width (Table 3).

Ungulate damage to the streambank has been markedly reduced in the fenced portion of Summit Creek (Table 2). Due to the decrease in stream area accessible to livestock, use of the stream has been increased above the fenced area and at the three water gaps. Streambank sloughing and trampling of vegetation continues at these locations. The BLM is studying the feasibility of removing water gaps and installing pipes to convey creek water to watering troughs. In the near future, the State of Idaho plans to protectively fence the 0.25 miles of Summit Creek above the Salmon District BLM study area.

In the fenced area, Summit Creek has narrowed at most permanent stations due to encroachment of vegetation along the banks. Streamflows remained constant from year to year, so a narrowing of the stream channel has caused the stream to deepen (Table 2). Figures 4 and 5 show the emergent vegetation encroachment that has caused changes in the stream profile.

Similar, but less dramatic, changes have occurred at most stations within the fenced portion of Summit Creek. Station 4 widened slightly because two separate channels

TABLE 2. Summit Creek habitat conditions within fenced area, as recorded in 1976 and 1978

Average of three transects at each station	Station 1		Station 2		Station 3		Station 4		Station 5		Station 6		Station 7		Station 8		Station 9[a]		Average for fenced area	
	1976	1978	1976	1978	1976	1978	1976	1978	1976	1978	1976	1978	1976	1978	1976	1978	1976	1978	1976	1978
Average water width (ft.)	13.7	13.7	20.0	15.5	17.0	15.0	12.7	13.0	15.3	14.0	12.3	9.7	13.7	12.7	18.0	16.7	22.0	22.5	16.1	14.8
Average riffle width (ft.)	11.0	9.3	10.0	7.0	11.8	10.0	6.3	5.0	8.7	7.7	6.7	4.3	5.7	4.0	18.0	15.0	8.5	12.0	9.6	8.2
Average pool width (ft.)	2.7	4.3	10.0	8.5	5.2	5.0	6.3	8.0	6.7	6.3	5.6	5.3	8.0	8.7	0	1.7	13.5	10.5	6.4	6.5
Average pool class	3.5	3.7	3.5	2.3	3.5	2.5	3.3	3.3	4.0	4.0	3.7	3.3	3.0	3.3	N/A	4.0	4.0	4.0	3.6	3.4
Average water depth (ft.)	0.7	0.7	0.7	1.0	0.7	0.9	0.8	0.9	0.7	0.9	0.7	1.1	0.8	0.9	0.5	0.7	0.8	1.0	0.7	0.9
Bank cover	2.8	2.8	3.8	3.5	2.5	2.2	2.8	2.7	1.5	2.0	2.2	2.5	2.0	2.2	1.3	1.8	1.2	2.0	2.2	2.4
Bank stability	3.2	3.3	3.2	3.6	3.2	3.7	3.0	3.8	2.7	3.8	3.0	4.0	2.7	4.0	2.7	3.5	2.2	3.8	2.9	3.7
Ungulate damage	2.5	3.2	3.5	3.8	3.8	3.8	3.7	4.0	2.5	3.8	3.0	4.0	2.0	4.0	2.7	3.8	2.0	4.0	2.8	3.8
Aquatic plants (ft.)	1.3	2.3	4.0	2.5	5.3	7.0	2.0	5.7	1.3	6.3	4.0	4.0	4.3	4.7	4.3	12.3	4.0	4.0	3.4	5.4

[a] Transects 1 and 2 only.

TABLE 3. Changes in Summit Creek habitat conditions above the fenced area in 1976 and 1978

Stream characteristics	Station 9[a]		Station 10[b]		Station 11[c]		Average for grazed area	
	1976	1978	1976	1978	1976	1978	1976	1978
Water width (ft.)	20.0	19.0	24.7	26.0	28.0	28.0	24.4	24.8
Riffle width (ft.)	9.0	4.0	11.8	15.7	28.0	28.0	15.2	15.8
Pool width (ft.)	11.0	15.0	12.9	10.3	0	0	9.2	8.9
Average pool class	4.0	4.0	3.7	3.5	N/A	N/A	3.8	3.8
Average water depth (ft.)	0.6	0.9	0.6	0.8	0.5	0.5	0.6	0.8
Bank cover	1.0	1.0	1.2	1.2	1.0	1.0	1.1	1.1
Bank stability	3.0	3.0	2.3	2.3	2.5	2.5	2.5	2.5
Ungulate damage	3.0	2.5	2.3	2.4	2.0	2.0	2.4	2.3
Aquatic plants (ft.)	18.0	12.0	10.3	16.3	8.0	2.0	11.6	11.6

[a] Transect 3 *only.*
[b] Average of Transect 1, 2 and 3.
[c] Transect 1 *only.*

converged; channel width increased at Station 9 because of lateral streambank cutting around an unmaintained trash catcher (Table 2).

Numerous islands of vegetation have become established on shoals and bars in Summit Creek. Figure 6 shows the formation of one of these islands, which created excellent trout cover.

Above the exclosure, the effect of unmaintained trash catchers on the stream profile makes analysis of the limited data difficult. Accumulation of debris on a trash catcher at Station 10 is responsible for both increased depth and increased width at this station (Table 3). An anomalous situation exists at Station 9, Transect 3—photographs indicate deteriorating stream conditions, but stream width has decreased and depth has increased (Table 3).

Recovery of streambank vegetation in the fenced area has helped stabilize banks that were eroding; Figure 7 illustrates this effect. Birch and willow bushes adjacent to the stream have also been reinvigorated and now provide additional fish cover relative to 1976.

Beneficial changes observed in streambank cover and stability within the fenced riparian area are summarized in Table 2. In contrast, bank cover and stability have remained unchanged in the unfenced stream section (Table 3). Since 1976, mats of aquatic vegetation have increased substantially at some transects within the exclosure (Table 2). This vegetation, mostly algae *(Nitella* sp.) and buttercup *(Ranunculus aquatillis),* harbored an abundance of mayflies, stoneflies, caddisflies, freshwater shrimp, snails, and other important trout food. Instream vegetation also provided cover for fish in exposed stream sections. Additional productivity attributable to this increased vegetation and increases in cover have improved trout habitat in Summit Creek.

Unfenced portions of Summit Creek exist below the Salmon District's study area, on public lands administered by the Idaho Falls District, BLM. Fish habitat, where livestock grazing continued, was not as desirable as in upstream sections that had been fenced. A habitat evaluation of Stations 1, 2 and 3 in the unfenced-grazed portion of Summit Creek indicated lower pool quality, less streambank cover, less streambank stability, more ungulate damage, and less instream vegetation than in Stations 1, 2 and 3 of the fenced-ungrazed section (Table 4).

Data for trout sampled during the study are listed in Table 5. It was recognized after fish sampling occurred that additional samples should have been taken to reduce statistical variability. Variation precluded statistically valid inferences from being made for the data except for station S-2 in the sagebrush-grass ungrazed area. At this

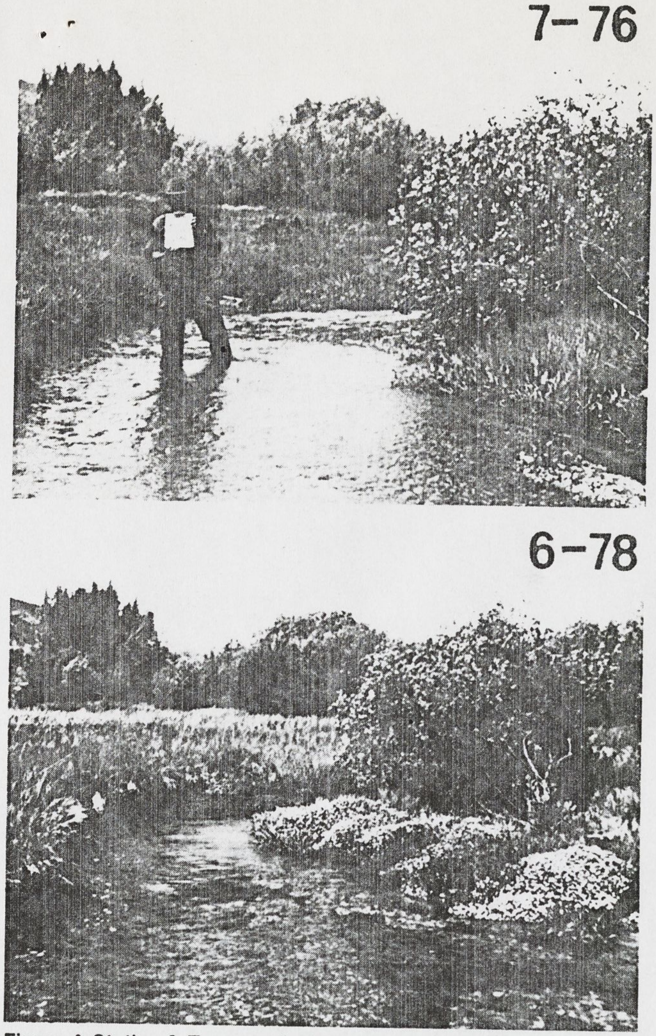


Figure 4. Station 6, Transect 1, showing vegetation encroachment responsible for narrowing and deepening Summit Creek in the fenced area between July 1976 (upper) and June 1978. Note in the lower photo the dense stands of rooted vegetation established in the creek.

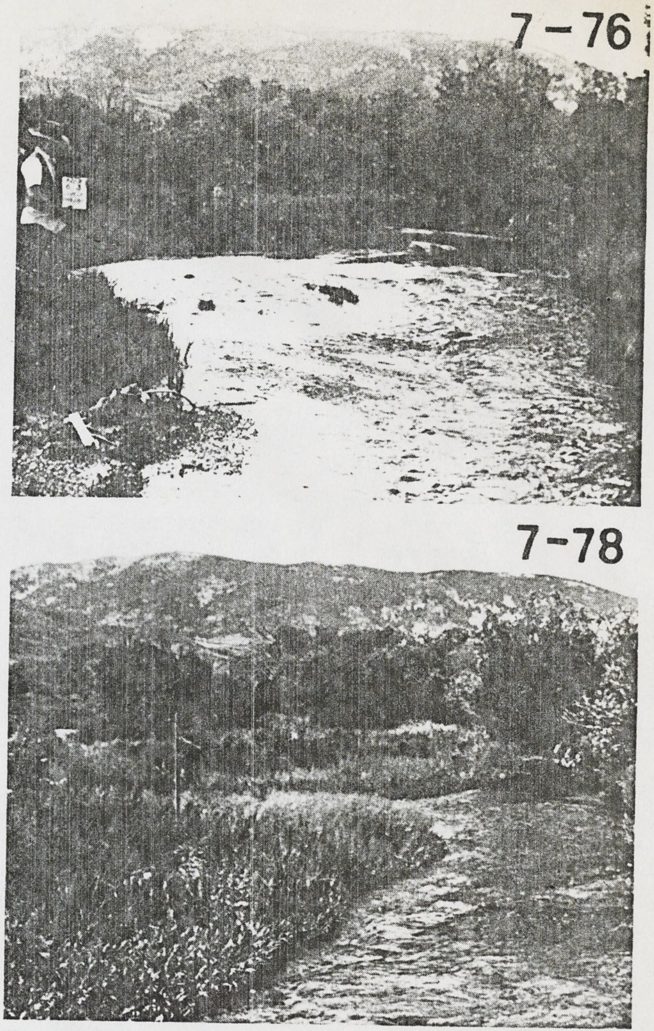


Figure 5. Station 6, Transect 3, showing vegetation encroachment responsible for narrowing and deepening Summit Creek in the fenced area. (Upper, July 1976; lower, July 1978)

TABLE 4. Habitat conditions existing in adjacent grazed and ungrazed areas of Summit Creek, Summer 1978. There were three transects per station.

Average	Grazed[a]	Ungrazed[b]
Water width (ft.)	13.2	14.6
Riffle width (ft.)	8.1	9.0
Pool width (ft.)	5.1	5.6
Pool class	3.5	2.8
Water depth (ft.)	0.7	0.8
Bank cover	2.1	2.8
Bank stability	2.8	3.6
Ungulate damage	2.8	3.6
Aquatic plants (ft.)	2.1	4.1

[a] Average of stations 1, 2 and 3, Idaho Falls District (Fig. 1).

[b] Average of Stations 1, 2 and 3, between campground and Idaho Falls District (Fig. 1).

TABLE 5. Trout population data for Summit Creek, Summer 1978

Trout length weight, and abundance	1F-2—sagebrush/grass-grazed	1F-1—brushy-grazed	S-1—brushy-ungrazed	S-2—sagebrush/grass-ungrazed
Rainbow trout $\hat{n}$[a] average length (cm)	26/13.8	89/15.9	144/15.6	313/18.5
Brook trout $\hat{n}$/average length (cm)	0	0	3/14.3[b]	50/17.0
Number of trout/surface acre	743	1,508	2,880	6,482
Weight of trout/per surface acre (g/lbs)	34,230/ 75.5	79,079/ 174.3	152,553/ 336.2	481,094/ 1060.6

[a] n = population estimate (Seber-Lecren method, 1967)

[b] A total of three brook trout were collected during sampling in S-1.

station, rainbow trout were more numerous ($P<.05$). Mean lengths of trout were also larger ($P<.001$) than at other locations (Fig. 8).

Brook trout were not collected in the grazed stream sections, whereas brook trout were collected in both ungrazed stream sections. Hatchery-reared fish from the previous year's stocking were not collected at any electrofishing station. Apparently, those hatchery fish not caught by anglers did not remain in the study areas.

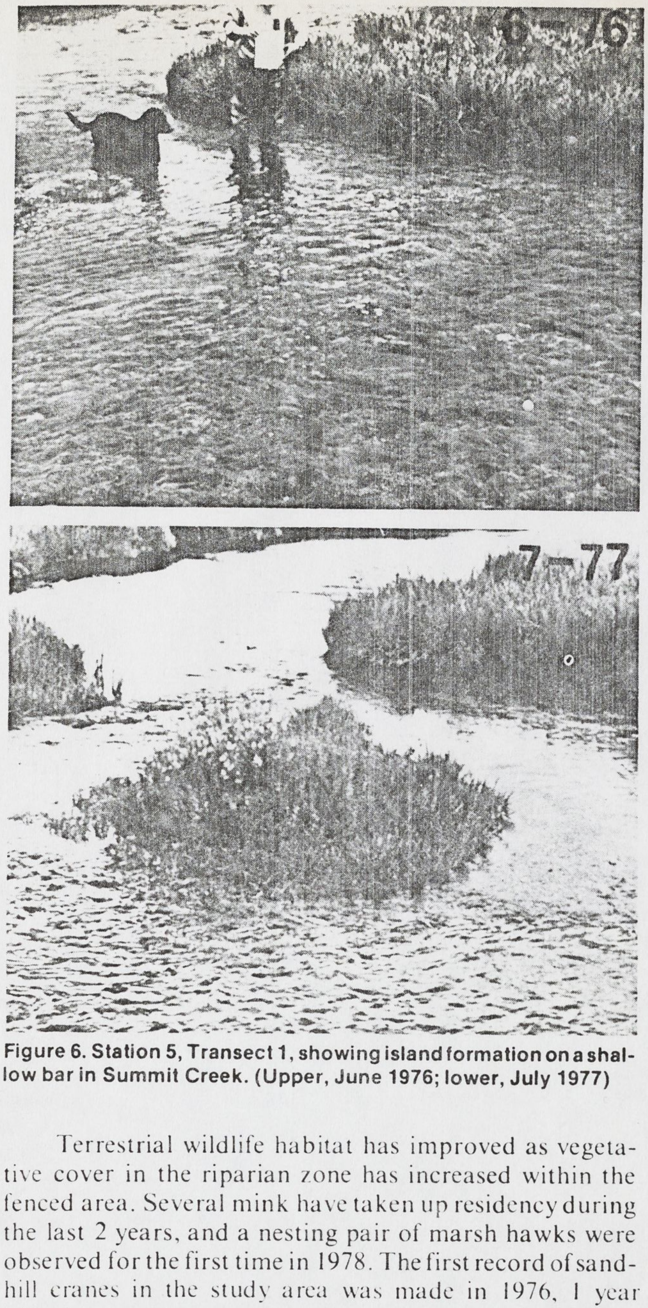


Figure 6. Station 5, Transect 1, showing island formation on a shallow bar in Summit Creek. (Upper, June 1976; lower, July 1977)

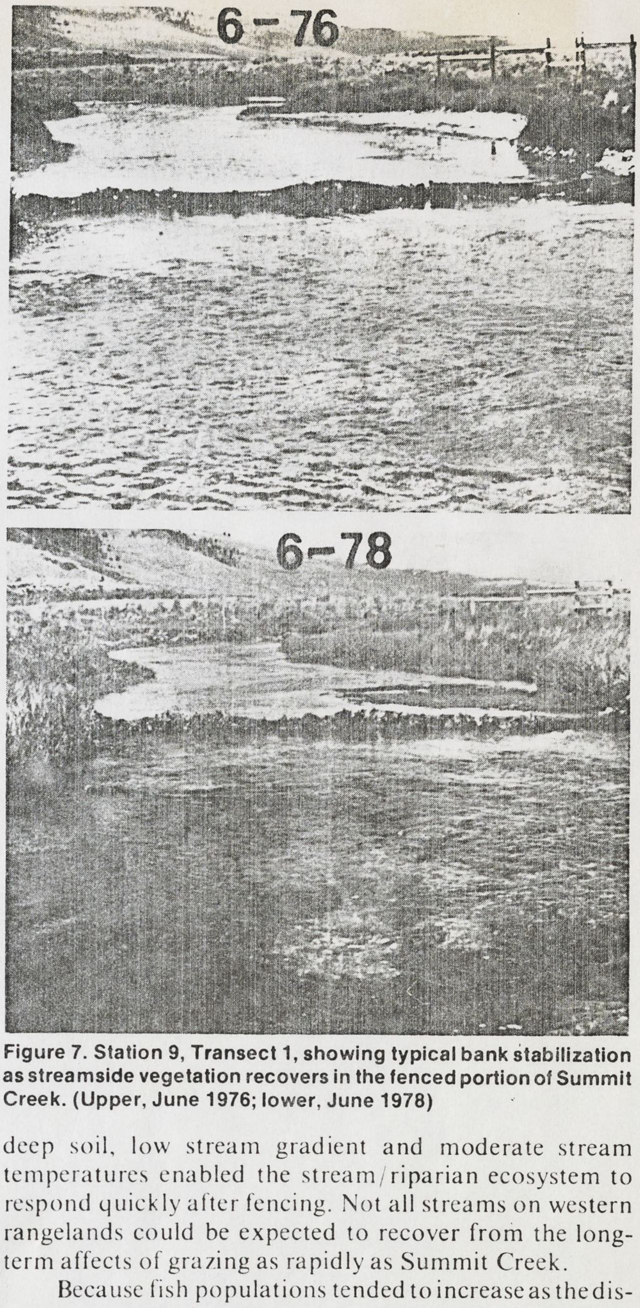


Figure 7. Station 9, Transect 1, showing typical bank stabilization as streamside vegetation recovers in the fenced portion of Summit Creek. (Upper, June 1976; lower, June 1978)

Terrestrial wildlife habitat has improved as vegetative cover in the riparian zone has increased within the fenced area. Several mink have taken up residency during the last 2 years, and a nesting pair of marsh hawks were observed for the first time in 1978. The first record of sandhill cranes in the study area was made in 1976, 1 year after fencing. American bitterns and great blue herons are more common now than before the riparian area was fenced.

Another benefit of the fencing project was reduced interactions between recreationalists and livestock. A primitive BLM campground located on Summit Creek was used by both people and livestock prior to the 1975 fencing project. Livestock-recreationalist encounters that may have occurred prior to fencing have been eliminated and harassment of livestock by recreationalists has been significantly reduced.

CONCLUSIONS

The rapid response of aquatic and riparian habitat to fencing continues to surprise those associated with the project. The unique environment of Summit Creek has contributed to dramatic habitat changes in only two growing seasons. The high water table, constant streamflow, deep soil, low stream gradient and moderate stream temperatures enabled the stream/riparian ecosystem to respond quickly after fencing. Not all streams on western rangelands could be expected to recover from the long-term affects of grazing as rapidly as Summit Creek.

Because fish populations tended to increase as the distance to Iron Springs decreased, not all of the observed differences in fish populations can be attributed to the influences of grazing on Summit Creek. Some of the disparity between populations may be a reflection of the stable temperature regimes closer to the springs.

Fish habitat protection provided by streambank fencing has negated the need for artificial structures intended to enhance trout production in this stream. Unmaintained trash catchers and digger logs installed in the upper reaches of Summit Creek should be removed. Several of these structures are causing silt accumulation (eliminating spawning sites), lateral bank scouring, and widening of the channel. Removal or alteration of these instream structures will allow the affected portions of Summit Creek to re-establish a stable, more productive stream environment. In addition, with the abundance of wild trout observed, it appears that yearly supplemental stocking of Summit Creek is unnecessary.

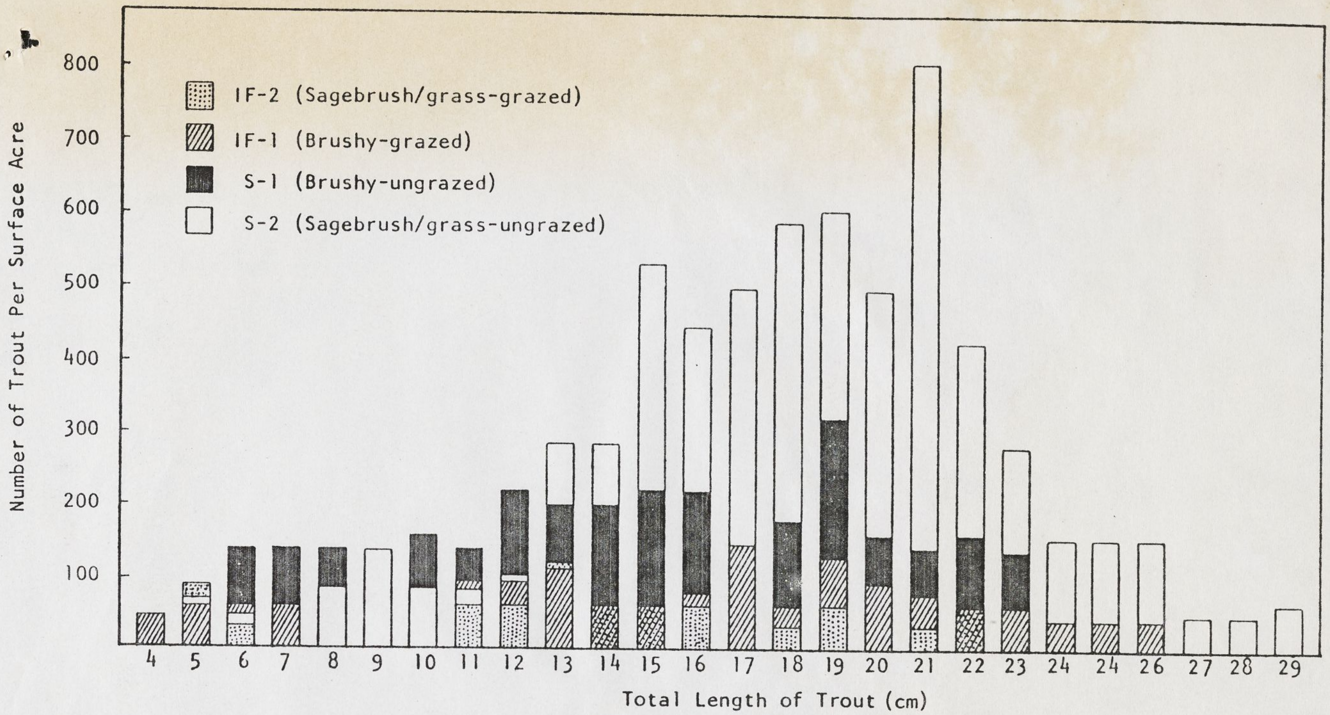


Figure 8. Length-frequency distribution of trout in grazed and ungrazed sagebrush/grass and brushy habitat of Summit Creek, 1978. Sample stations were 200 ft long. Data for rainbow and brook trout, combined, for Stations S-1 and S-2. Data for Stations 1F-1 and 1F-2 include rainbow trout only.

Continued study inclusive of improved experimental design methodologies of Summit Creek will provide better indications of the long-term response of the stream to exclusion of livestock grazing in the riparian area.

ACKNOWLEDGEMENT

We appreciate the assistance of numerous Bureau of Land Management and Idaho Department of Fish and Game personnel who helped in the organization, data collection, preparation, and review of this project. We also thank Dr. Carl Armour, U.S. Fish and Wildlife Service, and Dr. Bob Van Kirk, Humboldt State University, for reviewing early drafts of this paper.

LITERATURE CITED

Armour, C. L. 1977. Effects of deteriorated range streams on trout. Bureau of Land Management, Idaho State Office, Boise, Idaho. 7 p.

Duff, D. A. 1978. Livestock grazing impacts on aquatic habitat in Big Creek, Utah. Bureau of Land Management, Utah State Office, Salt Lake City, Utah. 15 p.

Hubbs, C. L., and R. R. Miller. 1948. The zoological evidence: Correlation between fish distribution and hydrographic history in the desert basins of western United States. Pp. 29-32; 76-77 *in* Blackwelder, T. (ed.) The Great Basin—With Emphasis on Glacial and Postglacial Times. Bull. Univ. Utah 38.

Seber, G. A., and E. D. LeCren. 1967. Estimating population parameters from catches large relative to the population. J. Animal Ecol. 36:631-643.

Stearns, H. T., L. Crandall, and W. G. Steward. 1938. Geology and Groundwater resources of the Snake River Plain in Southeastern Idaho. U.S. Geol. Surv. Water-Supply Paper 774. 268 p.

Van Velson, R. 1977. The rainbow trout in the North Platte Valley. Nebr. Game and Parks Commiss. Lincoln. 14 p.

White, Ray J., and O. M. Brynildson. 1976. Guidelines for management of trout stream habitat in Wisconsin. Wisc. Dept. of Natural Resources, Division of Conservation Tech. Bull. #39. 65 p.

Wineger, H. H. 1977. Camp Creek channel fencing plant, wildlife, soil and water response. Rangeman's Jour. 4(1):10-12.

Additional fish population data was collected on 20 September 1979.
A statistical analysis of the new data is available from Chuck Keller,
BLM, Box 430, Salmon, Id. 83467 (TX 208-756-2201)

Limnol. Oceanogr., 24(4), 1979, 613–626

Species-specific factors affecting predator-prey interactions of the copepod *Acanthocyclops vernalis* with its natural prey

Judith L. Li[1] *and Hiram W. Li*[1]
Wildlife and Fisheries Biology, University of California, Davis 95616

Abstract

Experiments of prey selection by *Acanthocyclops vernalis* demonstrate that many factors govern this process. Evidence from search and handling times required for complete consumption, behavioral observations, and carapace wound examinations indicated that body shape, carapace integrity, and mode of swimming were major influences on the selective process. Soft-bodied species were quickly and completely consumed; others were more difficult to handle and some of these were rejected. Escape strategies were different for each prey species, and the success of escape depended in part upon swimming direction relative to the mode of horizontal attack by *Acanthocyclops*. Size affects all of these characteristics because of correlative relationships to body allometry, carapace integrity, and swimming speed.

An understanding of invertebrate predator-prey relationships is important to understanding community dynamics of zooplankton communities in lakes (Allan 1976; Hall et al. 1976). Brooks and Dodson (1965) thought that competition would determine the size structure of zooplankton communities in the absence of vertebrate predation. However Dodson (1974*b*; Dodson et al. 1976) has shown that competition between large and small herbivores may not be as important as once suspected and suggests that invertebrate predators may be primarily responsible for shifts in community structure toward larger herbivorous zooplankters. Kerfoot (1977*b*) found that the major predators of *Bosmina* in Lake Washington are copepods, and that fish influence the copepod-*Bosmina* interaction by preying upon the copepods, not upon *Bosmina*.

The impact of invertebrate predators has often been examined by depletion studies wherein grazing rates are estimated through changes in prey density during the experiment (Hall 1964; McQueen 1969; Anderson 1970; Confer 1971). Gut dissection was used by Fryer (1957) as a more direct approach to feeding selectivity. In combination with data on zooplankton availability, this technique has become even more useful (Lewis 1977; Gophen 1977). However, a tendency for copepods to regurgitate and defecate may result in a large proportion of empty stomachs and in lost information (Clarke 1978; Li et al. in prep.). A third approach has been to observe behavioral patterns of a predator with a single prey species (Brandl and Fernando 1974; Kerfoot 1977*a*, 1978). Swift and Fedorenko (1975) widened the scope by studying two ambush predators, *Chaoborus americanus* and *Chaoborus trivittatus*, as they interact with naturally occurring prey. By incorporating an array of potential prey, we have examined prey selectivity by *Acanthocyclops vernalis*—a cruising search and attack predator—as described by Kerfoot (1978).

Our design incorporated single- and multiple-species prey experiments and emphasized the behavioral aspects of the predator-prey interaction. We compared capturing and handling techniques with different species of prey, the differential swimming behavior of prey species with and without the predator, and escape responses of the prey after initial contact with the predator. Previous work has suggested the importance of size (Anderson 1970; Zaret 1972; Kerfoot 1974) and shape (Kerfoot 1977*a*; Swift and Fedorenko 1975). Our observations allow us to relate the importance of these and other

---

[1] Current address: Oregon Cooperative Fishery Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis 97331.

Table 1. Comparisons of zooplankton sizes in Clear Lake vs. size used in experiments (mm).

Zooplankton	Species range	Experimental sizes
Rotifera		
Asplanchna girodi	0.4–0.7	0.4–0.95*
Keratella cochlearis	0.1–0.15	0.1–0.15
Synchaeta sp.	0.25–0.35	0.25–0.35
Cladocera		
Bosmina longirostris	0.2–0.45	0.2–0.45
Ceriodaphnia reticulata	0.2–0.8	0.2–0.8
Chydorus sp.	0.2–0.45	0.2–0.45
Daphnia pulex	0.4–2.0	0.4–1.0
Diaphanosoma leuchtenbergianum	0.5–1.1	0.5–1.1
Copepoda		
Acanthocyclops vernalis	0.6–1.0	0.6–1.0
Diaptomus franciscanus	0.4–1.6	0.4–1.0
Nauplii of: *Acanthocyclops vernalis* *Mesocyclops leuckarti* *Diaptomus franciscanus*	0.1–0.3	0.1–0.3

* Larger individuals grown in cultures.

morphological characteristics to prey vulnerability.

We thank G. W. Salt, P. R. Richerson, P. B. Moyle, and G. Redfield for advice and encouragement concerning research and the manuscript. We also thank W. Wurtsbaugh and R. Robertson for aid in the field and laboratory, as well as S. Cooper and S. I. Dodson for their helpful suggestions.

Methods and materials

Zooplankton came from Clear Lake, a shallow, eutrophic lake in the Coastal Range of California. Species used are listed in Table 1 and illustrated in Fig. 1. They were collected with a 3-liter self-activating trap, modified from a design by Schindler (1969). Water filtered from Clear Lake was used for all separation and experimental procedures. Zooplankton were taken from the lake and immediately concentrated in a separatory funnel where algae floated to the top and animals tended to swim toward the bottom opening. Before they were individually separated, zooplankton were transferred from the funnel to 60 × 15-mm petri dishes.

A dissecting microscope (10 to 30 power), equipped with an ocular micrometer, was used for separation procedures. Animals chosen as randomly as possible were separated with a micropipette connected by rubber tubing to a mouthpiece. Each animal was measured (to the closest 0.05 mm) and placed into an experimental dish. The predator had not been fed for about 24 h. After the addition of prey, the predator was added, and the experiment began. All experiments were conducted under constant light from a fluorescent lamp and at ambient room temperatures (about 20°–25°C).

Selection experiments—Selection experiments were conducted in petri dishes. We recorded species and sizes of prey selected or rejected, time required to kill and consume prey, and prey remains. Behavioral interactions were also documented. When the cause of death for a prey animal was uncertain, the experiment was not included in the analysis; only those prey which had been ingested, bitten, or injured were considered.

From October 1975 through September 1976, there were two sets of selection experiments: 108 experiments with two prey animals and 32 with five. The prey were no larger than the predator and were common zooplankters in the lake.

Reprinted from:
Proceedings, Forum--grazing and riparian/stream ecosystems.
p. 39-45. Oliver B. Cope, ed. Trout Unlimited, Inc. 1979.

Purchased by the Forest Service,
U.S. Department of Agriculture, for Official Use

LIVESTOCK GRAZING AND RIPARIAN/STREAM ECOSYSTEMS—AN OVERVIEW

William S. Platts
Research Fishery Biologist, Intermountain Forest and Range Experiment Station
U.S. Forest Service, Boise, Idaho

Streams have been subjected to damaging events since the day they were formed, initially by such natural events as glaciation, floods, climatic temperature changes, and droughts, and, more recently, by man colonizing along the stream banks and using the stream and its surroundings for mining, lumbering, livestock grazing, road construction, and sewage and waste disposal. These land uses, including livestock grazing, are of widespread concern to the public and land-management agencies. This forum and other seminars, symposiums, and workshops have been called to place grazing problems in perspective and to find solutions for the land manager.

The meetings held to date have determined (1) solutions to grazing problems are not easily found; (2) no single discipline possesses the skills and knowledge for all problem-solving; (3) past studies have identified many problems and offer some guidance; (4) more studies are needed to develop better understanding; (5) agencies responsible for the management of the streamside environment have not adequately considered the influence of livestock grazing; and (6) not all answers will be found in the near future.

It will take many small steps in the advancement of awareness and knowledge to get land managers to recognize and implement management practices that protect streams and their riparian environments.

✓ Land managers have often failed to recognize that streamside environments are different from other terrestrial systems, and so need specialized management. The stream, the riparian environment, and the adjacent upland environments require different land-management strategies. For example, even among riparian systems a broad riparian zone in a wet meadow has a different influence on a stream than a narrow riparian zone in a sagebrush ecosystem.

✓ Today's range-management guidelines do not call for different management strategies for the different habitat types; these guidelines cover only broad combinations of lands that mix riparian zones with the upland zones. A complication to the better balance of resource management is that scientists still differ on their interpretations of the effects of grazing strategies on stream and riparian habitats.

Authors express both sides of the livestock-fishery interaction subject. Behnke (1977) feels the best opportunity for increasing fish populations in the West is to improve fish habitats degraded by improper livestock grazing. This thinking may have merit, for 83 percent of the area of the 11 western states is in forest and range, and 70 percent of the 1.2 billion acres of forest and range in the United States is being grazed by livestock.

Heady *et al.* (1974), however, state that livestock grazing is being managed and integrated with other uses of federal lands and that there is no evidence that well-managed grazing of domestic livestock is incompatible with a high-quality environment. Leopold (1974) felt the opposite. He said that fish and wildlife habitat in western rangeland has experienced and is experiencing steady deterioration under existing multiple-use patterns. Furthermore, he said that livestock grazing may be having cumulative and unfortunate effects on land and water productivity.

These disagreements must be resolved because more and more pressure is being brought on land managers to increase the output of all resources. Grazing land is continually being reduced, which conflicts with the projected needs for an additional 70 million acres of range within the next 25 years to meet the demand for red meat (Heady *et al.* 1974). The increasing demand for energy development, recreation, and high-quality water will conflict with the demand for more red meat unless better management can be obtained.

The purpose of this forum is to allow cattlemen and fisheries biologists to exchange information and to reach a certain accord in regard to grazing practices beneficial to both. My charge is to present an overview of livestock-fishery interactions, setting the stage for papers identifying specific problems and/or presenting solutions.

HISTORY

Before the influx of European man into the western United States, natural ecosystems existed in which wild ungulates usually grazed compatibly with the range's carrying capacity. If for some reason the forage produced by a given range suddenly became scarce or non-existent, wild grazing animals either migrated to more favorable ranges or sustained a mortality, which brought the herds into balance with the range capacity.

Upon settling this country, European man soon recognized the possibility of using the vast rangelands for livestock production. As a result, the number of cattle on the western ranges and pastures has increased continually since 1875 (Wagner, in press). As a result of increased forage use and changes in or eradication of natural vegetation, much rangeland has been altered (Alderfer and Robinson 1974; Lusby *et al.* 1971; Sartz and Tolstead 1974). Since livestock are attracted to streamsides, overuse of the riparian zone has often resulted in widespread stream degradation.

Where the ranges were heavily stocked with livestock and confined within man-made barriers, changes in vegetation took place. Livestock trampled and compacted the soil, and the high-quality, fibrilar-rooted plants gradually gave way to shallow-rooted annual species or taprooted forbs or shrubs that could exist on areas with lowered water tables. Generally, these invader species are less palatable than plants with fibrilar roots and provide less nutrition and, often, only seasonal benefits for livestock. As soil compacted, infiltration of water into deep soils lessened and surface runoff increased. The accelerated rate of erosion had major effects on terrestrial and aquatic productivity. Rich topsoil was lost by the erosive action of wind and water, and the quality of streams receiving the eroded material was reduced. In addition, fine sediment smothered spawning and rearing areas, altering the habitat of fish.

As the livestock industry grew during the 19th Century and into the mid-1930's, the number of animals occupying the available range increased far beyond its carrying capacity. Overuse resulted in deteriorating ranges. The situation became so critical by the mid-1930's that the Taylor Grazing Act was enacted by Congress in 1934 to reverse the trend on the remaining rangeland in the public domain and to stabilize the livestock industry using these lands. Little attempt was made, however, to regulate grazing to conform to the ability of rangelands to sustain it, since there was little public interest in rangeland conditions at that time.

By the mid-1960's, management by allotment had become an accepted practice, and this is essentially the present situation. Public awareness of environmental quality, including rangelands, brought into clearer focus the original goals of the Taylor Act. The Resources Planning Act Assessment of 1975 projects increased demands on rangeland for the production of domestic livestock through the year 2020. With an expanding human population, it is inevitable that red meat production will have to be increased and more pressure will be placed on public ranges. Similar demands will be placed on production of white meat (fish).

In evaluating, through time, the effects of livestock grazing on the aquatic environment it must be recognized that different classes of livestock have different preferences of use in regard to streamside environments. Sheep prefer slopes and upland areas, but cattle prefer riparian habitats. Much former sheep range has been converted to what is primarily cattle range. Because cattle prefer streamside environments, deterioration of riparian habitat has been significant and much of the deterioration continues.

Because riparian environments are lumped into broad terrestrial environmental classifications, they become unidentifiable for land-management purposes. Often what is good for timber or range management is not good for riparian or stream managment.

The importance of riparian vegetation to wildlife has become apparent for the first time in this decade (Patton 1977). The importance of riparian vegetation to fish has been apparent for much longer. Fishery biologists were informed of problems and their input to land managers over the past two decades was inconsequential. Also, the leadership of the land-management agencies was paying little heed to those few scientists who had the foresight to alert them to ongoing habitat destruction. Land managers were devoting their attention to species management and to hatcheries rather than to habitat requirements.

Today, decisionmakers see the need for better management of streamside zones. Scientists who a few years ago would not undertake livestock-fishery interaction studies are now developing good data banks. These trends are encouraging and will lead to better livestock management.

FISHERY NEEDS

The habitat requirements of fish are a complex mixture that fishery biologists don't fully understand. However, biologists have completed some excellent biological work that makes possible a description of this habitat. Armour (1977) presents an excellent discussion of habitat needs of fish; this is reflected here.

Riparian Vegetation. Riparian zones are identified as those areas associated with surface water that reveal, through the vegetative complex, the influence of that water (Franklin and Dyrness 1973; Minore and Smith 1971). Riparian zones are the interface between terrestrial and aquatic environments. Riparian zones serve as a filter or a trap to stop pollutants moving from the terrestrial to the aquatic environment.

Riparian areas are the productive part of western grazing lands, usually containing the most productive timber and forage sites. Cattle forage on such areas more frequently than in adjacent, drier areas. Road builders often use riparian areas because of the gentle topography, and recreationists flock to such places for the scenic values associated with water.

Although most streamside zones are riparian, some are not. Examples of non-riparian sites are those areas where the sagebrush ecosystem reaches the water's edge, where the streamside zone is composed of bedrock, where streams are bordered by steep-sided canyon lands, or where streamside environments are composed of boulders or rubble. Non-riparian streamside zones can also be affected by livestock grazing, but usually to a lesser degree.

The streamside vegetation, in combination with undercut banks and streamside debris, provides fish cover. Binns (1976)[1] found cover highly significant in determining fish biomass in Wyoming streams. Boussu (1954) increased trout biomass over 200 percent by simulating cover in a South Dakota stream. Upon eliminating cover, trout biomass decreased. Streamside vegetation also provides a habitat for terrestrial insects that are in the fishes' diet, providing the organic material for about 50 percent of the stream's food energy (Cummins 1974).

Streamside vegetation shades the stream and decreases water temperature. Stream temperature for trout should not exceed 65° F and should be even lower for the critical spawning and incubation periods. Streams in the West, where riparian vegetation has been removed, are often too warm in the summer and too low in the winter. Streamside vegetation protects streambanks by reducing erosive energy, by helping deposits build the streambank, and by keeping the streambank from being damaged by ice, log debris, or animal trampling. Lack of vegetation exposes soils to erosion from rain or running surface water.

Stream Channels. Sedimentation in stream channels reduces instream cover for fish and depresses their food supply by filling channel interstices and reducing the substrate's potential to produce food. Large amounts of fine sediment kill fish embryos incubating in the stream-channel materials (Phillips *et al.* 1975). Large concentrations of fine sediment in spawning areas impede the intragravel subsurface waterflow, causing embryos to receive less oxygen and allowing toxic metabolic wastes to accumulate. Also, fish need instream cover, especially during their early years of development and during winter. Fine sediments filling the interstices reduce the amount of protective cover and force young salmonids to live in surface waters where they are more exposed to severe winter conditions.

Salmonids are dependent on aquatic and terrestrial invertebrates for their food. Fine sediments can cover the food-producing rubble and gravel channel areas, reducing the quality of the aquatic insect's habitat; this, in turn, impairs the quantity of food available for salmonids.

Streambanks. Streambanks bordering smaller streams (of stream order less than 6) provide the habitat edge needed to maintain high fish population densities. Fish often adapt their survival to this habitat edge because streambanks provide cover, control water velocities, and supply incoming terrestrial foods. The condition of the streambank often governs the water depths and velocities the fish must live in. Stable streambanks are an important part of the environmental quality needed by fish in small streams.

---

[1] Binns, N. Allen. 1976. Evaluation of habitat quality in Wyoming trout streams. Unpublished, on file at Wyoming Game and Fish Department, 260 Buena Vista, Lander, Wyoming.

Water Quality. Fish need high-quality water because this is their living medium. Water cannot be too warm or too cold, too fertile or too infertile, too fast or too slow, or too high or too low in dissolved gasses. Water of acceptable quality must first be present before the stream channel and streambank can form and contain it in a manner that fits the fish's habitat needs. Water that enters streams from the earth usually is of excellent quality to sustain fish. This new water needs only to be charged with certain gasses and nutrients to sustain fish. Most streams begin with high-quality water that deteriorates in the downstream areas because of land uses.

As water quality decreases and the water becomes more turbid, fish must survive in a medium in which they have difficulty seeing or moving. Often a less turbid area is not available to them. Migrating fish may avoid turbid streams, but fish forced to remain in turbid waters may have trouble feeding, using oxygen, and reproducing.

LIVESTOCK EFFECTS

Authors have already listed the effects of livestock grazing on fish and the aquatic environment (Platts, in press; Menke, in press; Armour 1977). This section summarizes these papers and discusses additional grazing effects.

Riparian Vegetation. Streamside vegetation is directly affected by grazing because riparian zones are usually grazed more heavily than are upland zones (Holscher and Woolfold 1953; Armour 1977). Duff (in press) found that when cattle were introduced into an area that had not been grazed for 4 years, the riparian vegetation declined 35 percent to prerest conditions in 6 weeks. Lorz (1974) found no difference in fish populations in ungrazed vs. grazed sections of the Deschutes River, Oregon when dense willow cover was on one or both banks.

Claire and Storch (in press) found the willow canopy in an exclosed area provided 75 percent more shade on the stream than areas outside the exclosure receiving year-round grazing. Gunderson (1968) found streamside cover was 77 percent more abundant in an ungrazed section of Rock Creek, Montana than in a grazed section.

Livestock grazing can affect the riparian environment by changing, reducing, or eliminating vegetation and by the actual elimination of riparian areas by channel widening, channel aggradation, or lowering of the water table. The most apparent effects on fish habitat are the reduction of shade and cover and resultant increases in stream temperature, changes in stream morphology, and the addition of sediment through bank degradation and off-site soil erosion. Stream temperatures increase in small headwater streams when riparian vegetation is removed and changes occur in the composition of fish communities in receiving streams downstream (Vannote, in press).

Detritus formed from terrestrial plants is a principal source of food for aquatic invertebrates and eventually for fish (Minshall 1976). A change in the quantity and quality of the detritus reaching the stream can severely interfere with natural conditions. This may result in a decline in the organisms fish eat and in a disruption of the stream's ability to process organic matter (Cummins 1974; Vannote, in press). Riparian vegetation is needed for the cycling of organic energy and for control of water temperatures.

Stream Channels. Stream-channel sedimentation caused by soil erosion on millions of acres of rangeland has long been recognized as a major problem. Lusby (1970), studying the effects of grazing on watershed hydrology in Colorado, found that ungrazed watersheds produced only 71-76 percent as much sediment as did grazed watersheds. Moore (1976)[2] estimated that rangelands in Environmental Protection Agency Region X (excluding Alaska) were second only to cropland in total sediment production. Duff (in press) found stream-channel widths were 173 percent greater in grazed stream reaches of Big Creek, Utah than in ungrazed stream reaches.

Streambanks. The sloughing-off and collapse of streambanks caused by improper livestock grazing probably affects fish populations most importantly. Streambanks erode because livestock congregate along streams for shade, more succulent vegetation, and drinking water. Livestock grazing off the vegetative cover and caving in over-hanging streambanks is one of the principal factors contributing to the decline of native trout in the West (Behnke and Zarn 1976). Winget and Reichert (1976) found that livestock grazing on selected Utah streams reduced bank stability 59 percent. In other Utah studies where livestock exclosures were used, streambank stability increased 100-740 percent (Berry and Goebel, in press; Duff, in press).

Marcuson (1977) found an ungrazed portion of Rock Creek, Montana had 2.5 times less channel erosion than an adjacent stream section that was grazed. Duff (in press) states that introduction of livestock into an ungrazed area for 4 years resulted in a 14-percent decline in streambank stability within 6 weeks. Hayes (1978), however, concluded that during spring runoff streambank degradation occurs more often and to a greater extent along an ungrazed streambank than along a grazed streambank. Seminar proceedings (Townsend and Smith, eds. 1977) and a symposium (Menke, in press) addressed interactions with wildlife and fish and their environments. Both publications concluded that livestock grazing degrades aquatic and riparian communities. Seminar members concluded that livestock grazing is the single most important factor limiting wildlife (including fisheries) production in the West. The symposium participants concluded that livestock grazing has severely reduced riparian vegetation and altered stream geomorphology, changes that adversely affect fish.

Water Quality. Claire and Storch (in press), studying the Deschutes River, Oregon alongside an exclosure that was ungrazed for 10 years, noted that the average stream temperature had dropped 12°. Busby and Gifford (in

---

[2] Moore, Elbert. 1976. Livestock grazing and protection of water quality. Environ. Prot. Agency, draft working paper. 123 p.

press) also found that grazing may be damaging water quality by affecting the hydrologic conditions within a given watershed. Skinner *et al.* (1974), Darling and Coltharp (1973), and Kunkle (1970) attribute the high coli count in streams to livestock grazing. Bacteria, along with sediment or chemicals, will degrade water quality.

Range practices can affect the condition of water in the runoff from a watershed, especially by increasing sediment. Photosynthesis is decreased by stream turbidity, and primary productivity is reduced. With primary productivity reduced, productivity of the entire ecosystem is decreased.

Fish Populations. The literature shows that streams modified by livestock grazing are wider and shallower. Generally, they have channels that contain more fine sediment, streambanks that are more unstable, banks that are less undercut, and higher summer water temperatures than natural streams. Behnke and Zarn (1976) identify livestock grazing as the greatest threat to the integrity of trout-stream habitat in the western United States. Behnke (in press) believes that rehabilitation of streams damaged by livestock grazing offers the best possibility of increasing wild, self-sustaining trout populations in the western United States.

Van Velson (Armour 1977) found, in Otter Creek, Nebraska, in an area fenced to exclude livestock, that within 3 years after fencing the stream improved from a non-producer to a major producer of trout. The stream width decreased, streambanks quickly stabilized, and summer water temperatures were reduced 2-5°. Clair and Storch (in press) found within an exclosure on the Deschutes River, Oregon that over a 10-year period of non-grazing the fish population shifted from predominantly dace *(Rhinichthys* sp.) to rainbow trout *(Salmo gairdneri* Richardson).

Marcuson (1977) found in Rock Creek, Montana that brown trout *(Salmo trutta* Linn.) biomass per unit area in a stream within a nongrazed section was 340 percent higher than in an adjacent stream section that was heavily grazed. In the same stream, Gunderson (1968) found trout were 27-400 percent more abundant in ungrazed sections than in grazed. Kennedy (1977) reported that trout were 240 percent higher in ungrazed sections of an Oregon stream than in grazed sections. Duff (in press) found trout populations 360 percent higher in ungrazed stream reaches of Big Creek, Utah than in grazed stream reaches. These studies strongly suggest that improper livestock grazing decreases both the quality and quantity of fish populations.

WHERE SHOULD THIS SYMPOSIUM TAKE US?

Hormay (1970) studied the effects of livestock grazing for many years and created some of the most widely used grazing strategies. Armour (1977) quotes Hormay as stating in personal communication that:

> Vegetation in meadows and drainageways is closely utilized under any stocking rate or system of grazing. Where this is the case, about the only way to preserve recreational values is to fence the area off from grazing. Reducing the livestock or adjusting grazing seasons usually will not solve the problem.

Under present financial limitations, it is impossible to fence all the streams in livestock grazing allotments. Currently, there is not enough money to maintain existing fences or to fence the most critical areas, let alone fence all streams. So, the problem is much larger than Hormay indicates; however, fencing should not be counted out as a management tool, for in many areas it may be the only way to protect streambanks and their vegetation.

The challenge is to use forums such as this to stride ahead by tackling problems and judging their solutions. Some of the situations this symposium should address are:

1. Which of the existing grazing systems are most compatible with the fishery resource?
2. What new innovations are needed to make livestock grazing more compatible with fishery needs?
3. Is there an ideal livestock grazing strategy for riparian areas?
4. What is required and how long does it take a stream altered by livestock grazing to return to near-natural condition?
5. What techniques are available or should be developed to reduce the recovery time for degraded streams?
6. How much, if any, of the fish population is lost because of livestock grazing streamside areas?
7. If streams need to be protected by fences, how much of each stream and what type of stream should be fenced?
8. How much vegetative canopy is needed on streambanks to prevent unacceptable stream temperatures?
9. How do different classes of livestock affect the riparian environment?
10. What are the first indicators that a stream is beginning to disintegrate or to improve from management of livestock?
11. How much forage use can the different vegetative types and streambanks support without unacceptable changes?
12. Are there times of the year when livestock grazing is less damaging than others?

These are avenues that some scientists have begun to explore. Claire and Storch (in press) rested a streamside area for 4 years and then grazed it annually each year after August 1, with no apparent damage to the fish population. Lorz (1974) concluded that dense willow stands would protect streambanks from being overgrazed.

This symposium will give us better insight into the effects of livestock grazing on riparian vegetation, water quality, stream-channel morphology, streambed condition, and streambank stability. In turn, better guidelines will be available to the resource manager for predicting the effects of the different grazing strategies on the condition and the productivity of stream and riparian systems. We must remember, however, that such meetings alone will not solve our problems. More facts will lead to greater understanding and to implementation of corrective actions for better land management. Corrective action has not been the case for stream and streamside management over the past 50 years. And, as a result, it is my belief that most stream environments are worse now than they were 10, 20, 40, or 80 years ago.

DISCUSSION

Livestock grazing can affect all four components of the aquatic system—streamside vegetation, stream-channel morphology, shape and quality of the water column, and the structure of the soil portion of the streambank. Livestock grazing can affect the streamside environment by changing, reducing, or eliminating vegetation bordering the stream. Channel morphology can be changed by sediment accrual, altered channel substrate composition, disrupted pool-riffle relationships, and channel widening. The water column can be altered by increasing water temperature, nutrients, suspended sediment, and bacterial counts, and by altering the timing and volume of water flow. Livestock can trample streambanks, causing banks to slough off, creating false setback banks, and exposing banks to accelerated soil erosion.

Documenting and evaluating effects of these alterations are difficult because nature causes similar alterations and effects. Fishery biologists are confronted with the problem of determining how different types of grazing systems affect the various aquatic components and how changes in these components affect fish health and survival.

Livestock grazing can cause annual microchanges in the environment that accumulate over many decades. These subtle changes are difficult to detect, whereas environmental changes from such sudden catastrophies as flood damage are usually readily observed and measured. Whether a stream has suffered a catastrophic degrading event or a long period of annual small events, the end point for fish can be the same. In either case, the stream and its fisheries have been damaged and, once stress is relieved, recovery may take years.

Streams and streamside zones are the most critical zones for multiple-use planning and offer the most challenge for proper management; therefore, stream habitats should be identified as separate management units to receive concentrated effort. Land-management agencies responsible for managing livestock grazing have not adequately considered the influence of grazing on streams and on their banks. Land managers often fail to recognize stream ecosystems and their importance as separate systems in their management programs. This oversight occurs even though studies have demonstrated that practices which protect streambanks from damage also enhance the potential of riparian vegetation to support other resources (Gunderson 1968; Marcuson 1977; Duff, in press).

The problem is that past management, or lack of it, has allowed streamside environments to deteriorate, and land managers do not have the information needed to correct the problems. Fishery biologists and range managers must concentrate on finding solutions to problems and on providing these solutions to the land managers, so that each riparian resource can be managed without infringing on other uses.

We must not continue to argue about whether livestock grazing degrades streams and their fisheries, but to use forums such as this to determine how to best manage streamsides so forage can be utilized and the fishery protected. The process will work only when forum participants take new knowledge back with them and apply it toward better range management. Better fisheries will be the result.

LITERATURE CITED

Alderfer, R. B., and R. R. Robinson. 1974. Runoff from pastures in relation to grazing intensity and soil compaction. J. Am. Soc. Agron. 39:948-958.

Armour, C. L. 1977. Effects of deteriorated range streams on trout. U.S. Bur. Land Manage. Idaho State Office, Boise, Idaho. 7 p.

Behnke, R. J. 1977. Fish faunal changes associated with land-use and water development. Great Plains-Rocky Mt. Geogl. J., 6(2):133-136.

________. Livestock grazing impacts on stream fisheries: Problems and suggested solutions. *In* (John Menke, ed.) Symposium on Livestock Interactions with Wildlife, Fisheries and their Environments, Sparks, Nev., May 1977. U.S. For. Serv. Pacific S.W. For. and Range Exp. Stn., Berkeley, Calif. (In press).

________, and M. Zarn. Biology and management of threatened and endangered western trouts. U.S. For. Serv. Gen. Tech. Rep. RM-28. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 45 p.

Berry, C., and P. Goebel. The use of exclosures in fishery management. Utah Acad. Sci. Arts and Lett. (Abstr.) Encyclia Vol. 55 (In press).

Boussu, M. F. 1954. Relationship between trout populations and cover on a small stream. J. Wildl. Manage. 18(2):229-239.

Busby, F. E., and G. F. Gifford. Impact of management on watershed values. *In* Sagebrush Ecosystem Symposium. Utah State Univ., Logan, Utah. (In press).

Claire, E., and R. Storch. Streamside management and livestock grazing: An objective look at the situation. *In* (John Menke, ed.) Symposium on Livestock Interactions with Wildlife, Fish and Their Environments, Sparks, Nev., May 1977. U.S. For. Serv. Pacific S.W. For. and Range Exp. Stn., Berkeley, Calif. (In press).

Cummins, K. W. 1974. Structure and function of stream ecosystems. Bio-Sci. 24:631-641.

Darling, L., and G. Coltharp. 1973. Effects of livestock grazing on the water quality of mountain streams. Pp. 1-8 *in* Water-Animal Relations Symposium Proc., U.S. Dep. Agric., Agric. Res. Serv., Kimberly, Idaho.

Duff, D. A. Livestock grazing impacts on aquatic habitat in Big Creek, Utah. *In* (John Menke, ed.) Symposium on Livestock Interactions with Wildlife, Fisheries and their Environments, Sparks, Nev., May 1977. U.S. For. Serv. Pacific S.W. For. and Range Exp. Stn., Berkeley, Calif. (In press).

Franklin, J. F., and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. U.S. For. Serv. Gen. Tech. Rep. PNW-8. Pacific N.W. For. and Range Exp. Stn., Portland, Ore. 417 p.

Gunderson, D. R. 1968. Floodplain use related to stream morphology and fish populations. J. Wildl. Manage. 32(3):507-514.

Hayes, F. 1978. Streambank stability and meadow condition in relation to livestock grazing in mountain meadows of central Idaho. M.S. Thesis, Univ. of Idaho, Moscow. 91 p.

Heady, H., T. W. Box, John E. Butcher, *et al.* 1974. Livestock grazing on federal lands in eleven western states. J. Range Manage. 27(3):174-181.

Holscher, C., and E. Woolfold. 1953. Forage utilization by cattle in the northern Great Plains range. U.S. Dep. Agric. Circ. No. 918. 27 p.

Hormay, A. L. 1970. Principles of rest-rotation grazing and multiple use land management. Training text 4(2200). U.S. For. Serv., Washington, D.C.

Kennedy, C. 1977. Wildlife conflicts in riparian management: Water. Pp. 52-58 *in* Symposium on Importance, Preservation and Management of Riparian Habitat. U.S. For. Serv., Gen. Tech. Rep. RM-43.

Kunkle, S. 1970. Sources and transport of bacterial indicators in rural streams. *In* Symposium on Interdisciplinary Aspects of Watershed Management, Montana State Univ., Bozeman. 31 p.

Leopold, A. S. 1974. Ecosystem deterioration under multiple use. Pp. 96-98 *in* Proc. Wild Trout Management Symposium, U.S. Fish and Wildl. Serv. and Trout Unlimited, Denver, Colo. 103 p.

Lorz, H. W. 1974. Ecology and management of brown trout in Little Deschutes River. Oreg. Dep. Fish and Wildl. Fish. Res. Rep. 8. 49 p.

Lusby, G. 1970. Hydrologic and biotic effects of grazing vs. non-grazing near Grand Junction, Colorado. J. Range Manage. 23:256-260.

________, V. H. Reid, and O. D. Knipe. 1971. Effects of grazing on the hydrology and biology of the Badger Wash Basin in western Colorado, 1953-66. U.S. Geol. Surv. Water Supply Paper 1532-D. 90 p.

Marcuson, P. E. 1977. The effect of cattle grazing on brown trout in Rock Creek, Montana. Mont. Dep. Fish and Game Fed. Aid Proj. F-20-R-21-11a. 16 p.

Menke, J. (ed.). Symposium on livestock interaction with wildlife, fisheries and their environments, Sparks, Nev., May 1977. U.S. For. Serv., Pacific S.W. For. and Range Exp. Stn., Berkeley, Calif. (In press).

Minore, D., and C. E. Smith. 1971. Occurrence and growth of four northwestern tree species over shallow water tables. U.S. For. Serv. PNW-160, Pacific N.W. For. and Range Exp. Stn., Portland, Ore. 9 p.

Minshall, G. W. 1976. Role of allochthonous detritus in the trophic structure of a woodland springbrook community. Ecology 48:139-149.

Patton, D. R. 1977. Riparian research needs. Pp. 80-82 *in* Importance, Preservation and Management of Riparian Habitat, A Symposium. U.S. For. Serv. Gen. Tech. Rep. RM-43, Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

Phillips, R., R. Laritz, E. Claire, and J. Moring. 1975. Some effects of gravel mixtures on emergence of coho salmon and steelhead trout fry. Trans. Amer. Fish. Soc. 104(3):461-466.

Platts, W. S. Livestock interaction with fish and aquatic environments: Problems in evaluation. 43rd N. Amer. and Nat. Resour. Conf. (In press).

Sartz, R. S., and D. N. Tolstead. 1974. Effect of grazing on runoff from two small watersheds in southwestern Wisconsin. Water Resour. Res. 10:354-356.

Skinner, Q., J. Adams, P. Rechard, and A. Bettle. 1974. Effects of summer use of a mountain watershed on bacterial water quality. J. Environ. Qual. 3:329-335.

Townsend, J. E., and R. J. Smith (eds.) 1977. Proceedings of a seminar, Improving Fish and Wildlife Benefits in Range Management (Washington, D.C., March 1976). U.S. Fish & Wildl. Serv. Biol. Serv. Prog. 118 p.

Vannote, R. O. Thermal gradients in natural streams and aquatic insect strategies. Proc. Phil. Acad. Natl. Sci., Ground Water Res. Center, Acad. Natl. Sci., Avondale, Pa. (In press).

Wagner, F. H. Effects of livestock grazing and livestock industry on wildlife. *In* (John Menke, ed.), Symposium on Livestock Interactions with Wildlife, Fisheries and their Environments, Sparks, Nev., May 1977. U.S. For. Serv. Pacific S.W. For. and Range Exp. Stn., Berkeley, Calif. (In press).

Winget, R., and M. Reichert. 1976. Aquatic survey of selected streams with critical habitats on NRL affected by livestock and recreation. Unpublished final report, U.S. Bur. of Land Manage. Utah State Office, Salt Lake City. 109 p.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1979-0-677-019/21

SEASONALITY OF FISHES OCCUPYING A SURF ZONE HABITAT IN THE NORTHERN GULF OF MEXICO

Timothy Modde[1] and Stephen T. Ross[2]

ABSTRACT

The ichthyofauna occupying the surf zone habitat of Horn Island, Mississippi, between 1975 and 1977 was dominated by immature clupeiform fishes. The dusky anchovy, *Anchoa lyolepis*, and the scaled sardine, *Harengula jaguana*, together constituted 80.2% of the 154,469 fishes collected. The greatest number of fishes were collected in the late spring and summer, followed by a secondary peak in late winter. Occurrence of the fishes within the surf zone is divided into three categories according to seasonal utilization: spring and summer, summer only, and winter. Factors affecting numerical abundance within the surf zone differed among the most frequently appearing species. Differences in the numbers of clupeiform fishes—*A. lyolepis*; *A. hepsetus*, striped anchovy; and *H. jaguana*—were more closely associated with diel changes including tidal stage and time of day. The abundance of the Florida pompano, *Trachinotus carolinus*, and the gulf kingfish, *Menticirrhus littoralis*, were more dependent upon seasonal effects such as temperature.

Relatively few studies have investigated the role of exposed surf zone habitats in the early life history of fishes. While Springer and Woodburn (1960) described the surf zone region as an "extreme habitat offering little environmental diversity," this habitat does provide several benefits to fishes. Advantages suggested by Warfel and Merriman (1944) included the abundance of food (concentrated by incoming tides), increased metabolic efficiency via heat acquisition, and protection from predation.

Surf zone ichthyofaunas are numerically dominated by relatively few species. For instance, McFarland (1963) stated that 60-80% of the ichthyofauna occupying the surf regions along the south Atlantic and Texas coasts was comprised of only a few species. Gunter (1958) found high similarity in species composition between Mustang Island, Texas, and Atlantic coast surf zones and suggested that the surf zone region was dominated by a small group of species which remained relatively constant over wide geographical areas.

Much of the literature regarding shore zone fishes is restricted to either descriptions of species occurrence or seasonal characterizations, seldom exceeding one annual cycle. Reid (1955a, b), Schaefer (1967), and Hillman et al. (1977) have sampled the same habitats in successive seasons and have observed annual changes in species composition. Fewer studies have attempted to relate physical or biological parameters to the abundance of fishes within the shallow beach habitat. Gunter (1945) and Warfel and Merriman (1944) attributed the distinct seasonal fluctuations in fish abundance to temperature. Both Anderson et al. (1977) and de Sylva,[3] using multiple regression analyses and crosstabulation, respectively, also indicated that temperature was a significant factor in determining seasonal abundance of the most numerous fish species.

The present study describes seasonal and annual variations in fish species composition and the factors affecting fish occurrences within the surf zone of Horn Island, Miss., a barrier island in the northern Gulf of Mexico.

METHODS

The study area was located along the southern shore of Horn Island, Jackson County, Miss. Horn Island is in a chain of barrier islands lying parallel to the Mississippi-Alabama Gulf coast (Figure 1). The island lies approximately 14 km off the mainland and has a length of 19 km with a maximum width of 1.2 km. The beach is partially protected from oceanic wind-driven waves by a series of sand

---

[1] Department of Biology, University of Southern Mississippi, SS Box 5018, Hattiesburg, Miss.; present address: Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, SD 57007.

[2] Department of Biology, University of Southern Mississippi, SS Box 5018, Hattiesburg, MS 39401.

[3] de Sylva, D. P. 1962. Fishes and ecological conditions in the surf zone of the Delaware River estuary, with notes on other species collected in deeper water. Univ. Del. Mar. Lab Inf. Serv. 5, 164 p.

Manuscript accepted April 1980.

[NOAA]

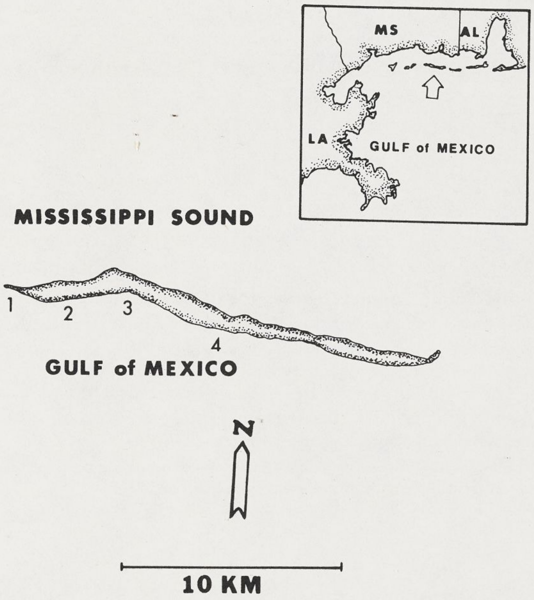


FIGURE 1.—Map of Horn Island, Jackson County, Miss., showing the four sampling areas. The southern side of the island represented the windward shore.

bars which extend the length of the island. The surf zone habitat is characterized by a sand substrate, the absence of any rooted vegetation, and sufficient wave activity to be categorized as a high energy beach (Odum and Copeland 1974).

We began sampling in April 1975 along the southwestern edge of the island (Station 1), and collections were made at about 7-wk intervals until November 1975. From May 1976 to November 1977 we sampled four stations along the windward shore of Horn Island (Figure 1) at about 5-wk intervals (Table 1). We also sampled sheltered beach areas adjacent to Stations 3 and 4 during the summer of 1976. All of the above collections were taken between 0900 and 1600 h c.s.t. (central standard time).

TABLE 1.—Sampling dates for fish taken from the surf zone habitat on the southern shore of Horn Island, Miss., between April 1975 and November 1977. Each collection represents a set of seine hauls at a specific location.

	1975		1976		1977	
Season	Date	No. of collections	Date	No. of collections	Date	No. of collections
Winter			13 Mar.	6	22 Jan.	4
					17 Mar.	5
Spring	12 Apr.	3	23 Apr.	4	28 Apr.	5
	21 June	2	28 May	7	27 May	8
Summer	12 Aug.	3	25 June	11	27 June	5
			23 July	8	23 July	5
			24 Aug.	5	17 Sept.	4
			2 Sept.	8		
Fall	18 Oct.	4	1 Oct.	6	23 Nov.	4
			4 Dec.	5		

Every month between March and September 1976 (excluding August) we sampled either Station 1, 3, or 4 over a 24-h period, taking samples at about 4-h intervals. The choice of station was based in part on the availability of a safe anchorage for our boat. In order to compare data throughout the study, collections made between 1600 and 0900 h were not included in seasonal or annual comparisons.

Fishes were collected with a 3.2 mm Ace[4] mesh bag seine measuring 9.1 × 1.8 m. Hauls were made perpendicular to the beach face beginning 16-18 m offshore. The area sampled extended from the swash zone to the midlongshore trough, and we made an effort to take regular samples only in areas directly exposed to surf. We continued seining at each location until no additional new species were collected; usually 5-9 hauls sufficed. Each collection at each location was thus comprised of a successive number of seine hauls. Fishes collected from all seine hauls at a single station were pooled for analysis. Catch-per-effort data from all stations were pooled to provide monthly means. The study included 613 seine hauls.

Species similarity by months was analyzed by the unpaired group arithmetic average clustering (UPGMA) method (Sneath and Sokal 1973). Only the 15 most abundant species, which were collected in at least 15% of the locations sampled, were analyzed. Pair similarity based on species presence or absence (Odum 1971) was determined by:

$$S = 2C/A + B$$

where C = number of species common to samples a and b,
A = number of species in sample a,
B = number of species in sample b.

We used stepwise multiple regression to define the dominant factors associated with the abundance (fish per seine haul) of the five most frequently occurring species. Environmental parameters selected as independent variables were

---

[4] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

United States
Department of
Agriculture

Forest Service

Pacific Northwest
Forest and Range
Experiment Station

General Technical
Report
PNW-146
November 1982

Evaluating Projects for Improving Fish and Wildlife Habitat on National Forests

Fred H. Everest and Daniel R. Talhelm

Authors

FRED H. EVEREST is a research fisheries biologist, Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon 97331. DANIEL R. TALHELM is a fisheries and wildlife economist, Michigan State University, East Lansing, Michigan 48104.

Common and Scientific Names

Common name	Scientific name
Coho salmon	*Oncorhynchus kisutch* (Walbaum)
Chinook salmon	*Oncorhynchus tshawytscha* (Walbaum)
Cutthroat trout	*Salmo clarki* Richardson
Rainbow (steelhead) trout	*Salmo gairdneri* Richardson

Abstract

Everest, Fred H.; Talhelm, Daniel R. Evaluating projects for improving fish and wildlife habitat on National Forests. Gen. Tech. Rep. PNW-146. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982. 12 p.

Recent legislation (P.L. 93-452; P.L. 94-588) has emphasized improvement of fish and wildlife habitat on lands of the National Forest System. A sequential procedure has been developed for screening potential projects to identify those producing the greatest fishery benefits. The procedure — which includes program planning, project planning, and intensive benefit/cost analysis — has nationwide application for both fish and wildlife projects. Fisheries and wildlife values are difficult to assess and available estimates are far from ideal, but better estimates are gradually becoming available.

Keywords: Habitat improvement, wildlife habitat, cost/benefit evaluation, program planning, salmonids.

Contents

Introduction

In the 1970's, Congress formally recognized the potential value of improving fish and wildlife habitat on the National Forests by requiring comprehensive planning for fish and wildlife on National Forest System lands (Sikes Act, P.L. 93-452, as extended in 1974). USDA Forest Service budgets for habitat improvement have grown steadily in recent years, and the National Forest Management Act of 1976 (P.L. 94-588) provided the option to use Knutson-Vandenberg funds for habitat rehabilitation and enhancement within designated timber sales. These recent actions have enabled forest managers to initiate a positive program to improve fish and wildlife habitat on the National Forests. But because more potential projects exist than can be completed annually with existing funds, projects that provide the greatest benefits must be selected.

Biologists, economists, and others who participate in the planning and selection process have difficulty comparing project alternatives objectively because the range of potential projects is so great, and little information has been available for estimating expected benefits from projects. Thus standard, objective evaluation tools, such as benefit/cost analyses, have been difficult to use. Ideally, projects can be compared by evaluating the benefits and costs of each alternative. Project benefits can be defined as the degree to which people are better off with the project than without it. This can be estimated in terms of the aggregate willingness of people to pay to have the project rather than to go without.

Benefit/Cost Concepts

Unfortunately, this information is not available for most fish and wildlife projects because of the lack of conventional markets for recreational use of fish and wildlife. How willing recreational users are to pay for changes in the fish and wildlife resource is not generally known. Most economic studies of recreation are not directly usable either because they evaluate something other than willingness to pay for resource use (such as studies of expenditure patterns), or because they estimate willingness to pay for broad, drastic choices (such as the willingness of anglers to pay for a State's entire coastal anadromous fishery rather than not have it at all, called the "all-or-none" value), rather than willingness to pay for the much smaller effects of specific projects (Talhelm 1980). All-or-none values can differ greatly from project values. Even the value of fisheries resources to the commercial fisheries sector is difficult to estimate. The commercial fisheries' net willingness to pay for improved fishing would be the market value of the additional fish minus additional costs of harvesting and bringing them to market. The market values may be well known, but the costs are not.

Biologists working in the National Forests usually cannot obtain the proper kinds of value information for each alternative, so they must use shortcut procedures and rules of thumb instead. Our objective is to explain and illustrate some useful procedures for planning fish and wildlife programs and projects for National Forests, and for estimating fish and wildlife values—and to contrast all of these with ideal procedures. Procedures are illustrated with a specific example from the Siskiyou National Forest of southwest Oregon. Before we discuss procedures for program and project planning, however, we first present a brief explanation of benefit/cost concepts (adapted from Francis et al. 1979).

When we ask whether the benefits of rehabilitation will exceed the costs, what are we really asking? One answer is that we are asking whether, over the long run, the gains outweigh the costs. If so, theoretically, the gainers could pay the capital and labor costs and compensate any losers so that in the end, none would feel worse off and at least one group would feel better off. This is the same question you implicitly ask yourself when you decide whether you should purchase any product in the market. If you voluntarily purchase something at a given price, you do so because you think you will be better off with the product, and your payment will have compensated the producers. Both you and the producers have volunteered to buy and sell, so you both must have decided the exchange was in your best interests. The main difference in rehabilitation is that the beneficiaries of public decisions may not be the only ones who pay the costs, and the losers are not always compensated.

Compensation is considered adequate for our purposes when everyone feels at least no worse off, after the change has been produced and compensation has been paid. Adequate compensation, then, is the minimum required to make people who have given up something feel as well off as before. In other words, it is their willingness to accept compensation. In analyzing public decisions, economists look at two values: the benefits, measured in terms of the maximum the public would be willing to pay; and the costs, measured in terms of the minimum the public would be willing to accept as compensation. These values are easily measured in an ongoing market where payments are offered and accepted, but where is the market for rehabilitation projects?

If long-run benefits exceed long-run costs, the project is probably a good choice for society unless better choices are available because the social gains outweigh the social costs—a gain in aggregate welfare for society. This is because if compensation were paid no one would be worse off and at least some members of society would be better off. These gains and losses can also be assessed in ways other than through economic analysis (such as through political processes or Delphic methods), and sometimes that is necessary if the benefits, costs, or both cannot be accurately estimated. Accurate economic benefit/cost analysis, however, has the advantage of providing confidence that we have arrived at the best decision.

Although benefit/cost analyses assess social choices in an important sense, they do so only in special, confined ways. Certain social values or considerations are usually not addressed in benefit/cost analyses. Those considerations are social equity; human rights or other ethical judgments; economic impacts; and major shifts in social policy.

Social equity in the economic sense is usually thought of as the distribution of income or wealth among members of our society. Because the benefits and costs of projects are measured in terms of willingness to pay or to accept compensation, both of which depend upon the current distribution of wealth, all benefit/costs analyses depend to some extent on current distribution of income. The results might differ if income were distributed differently. In fact, whether or not gainers actually pay losers will have some effect on income distribution, so even this could affect the results of a benefit/cost analysis. In addition, if the existing distribution of income in society were considered unfair, then the results of any benefit/cost analysis might also be considered unfair. The effects of income distribution are ignored in benefit/cost analyses. But political and administrative decisionmaking processes often consider, in one form or another, the equity effects of income distribution.

Human rights and other ethical judgments are also usually ignored in benefit/cost analyses. Obviously these are based on human biases, but benefit/cost analyses do not attempt to distinguish good from bad ethics. Political judgments may, however, and those judgments can override benefit/cost analyses.

To economists, economic impacts are measures of the transfer of income, employment, or both from one region to another or from one sector of the economy to another as a result of some change in the economy. You often hear about dollars spent by recreationists at motels, restaurants, and gas stations, or that commercial fisheries not only employ the fishers themselves but also the processors and perhaps local restaurant personnel. Secondary impacts are usually not relevant in benefit/cost analyses because they are not direct measures of benefits or costs, but of the location of economic activity. The only aspects of economic impacts that should be included in benefit/cost analyses are the positive or negative values of alleviating or causing unemployment of capital, labor, or both, and the value of progress toward or away from any social goal of transferring income and employment from one region or economic sector to another. Communities and regions are often concerned with economic impacts because they greatly influence patterns of local growth and community integrity. These considerations are more likely to form part of a political judgment than a benefit/cost analysis because economists have great difficulty measuring the values represented by such concerns.

Finally, the "macro" judgments of any society are usually considered beyond the useful scope of benefit/cost analysis. For example, the decision to open western North America to homesteading and the decision to put a man on the moon by 1970 both represent deliberate political choices resulting in major changes for society. These kinds of decisions lead to changes that are uncertain or even totally unanticipated at the outset. The decisions are made only because of a strong conviction that the ensuing benefits will more than offset the costs. A traditional, detailed benefit/cost analysis is neither possible nor would it increase public confidence in the merits of this kind of decision. Any major redirection of society or its economy will in itself change the values we rely upon to estimate dollar benefits and costs, thereby reducing the reliability of the analysis.

Social equity and human rights must be considered separately and weighed against the benefit/cost analysis of any project. A logical approach would be to complete the benefit/cost analysis and then to follow any explicit Forest Service guidelines, or if these are unavailable, to ask an advisory committee to rerank projects on the basis of human values. Public hearings could be held or elected representatives might rerank the projects. Obviously, any of these processes might result in socially worse rankings than the original ones, or the costs of the reranking process may be greater than the benefit received. That social equity and human rights values would significantly alter many fish and wildlife project analyses for National Forest projects is unlikely, however.

Program Planning

Program planning—the initial step—is a broad evaluation of the entire range of potential projects, with the objectives of identifying the kinds of projects worthy of more detailed evaluation in the project-planning stage, and understanding how these projects relate to each other and to other goals and objectives of the Forest and of related agencies. Ideally, the benefits and costs of each possible project would be evaluated. In this context, program planning can be viewed as a generalized benefit/cost evaluation, accepting or rejecting whole, broad categories of possible projects to permit the planner to concentrate on the most likely projects.

This process is often not even recognized as a form of benefit/cost analysis. Planners often speak of identifying needs and types of projects that would meet those needs. On closer examination, however, needs are simply results likely to be highly beneficial. An area with few angling opportunities relative to the potential angling effort is spoken of as having a deficit of angler days or a need of so many angler days. In other words, the benefits of providing for additional angler days there are likely to be great. Quantifying potential benefits would be a much more precise way of understanding need, but shortcut procedures are more expedient at this stage.

Identifying Needs

Program development must be responsive to local and national needs for recreation, commercial fishing, or enhancement of habitat for threatened or endangered species. Statewide comprehensive plans, State fish and wildlife plans, and the Endangered Species Act of 1973 (P.L. 93-205) are examples of documents that can be used to identify needs for habitat improvement.

Table 1 — Deficits in catch of anadromous and resident salmonids in southwest Oregon in 1980, and Siskiyou National Forest's potential to eliminate deficits by enhancing habitat

Salmonids	Deficit		Enhancement potential
	Number of fish caught	Activity-days	
ANADROMOUS			
Spring chinook	400	3,000	Low
Fall chinook	1,000	6,000	High
Coho	1,000	1,000	Medium
Summer steelhead	400	3,000	Low
Winter steelhead	1,000	5,000	High
Cutthroat	300	300	High
RESIDENT			
Trout in streams	18,000	7,000	Low
Trout in lakes	74,000	30,000	Low

An example from southwest Oregon illustrates how these needs are identified. Data in the Oregon Statewide Comprehensive Plan (USDA Forest Service 1976) indicated that a deficit in supply of most anadromous and resident salmonids occurred within the State in 1980. The most serious deficits in southwest Oregon were associated with fisheries for fall chinook salmon, coho salmon, winter steelhead, and resident trout in lakes and streams (table 1).

Habitat improvement on the Siskiyou National Forest could eliminate a portion of the deficit in recreational angling. The Forest contains portions of 11 river basins producing anadromous salmon and trout; it supports one of the largest anadromous fisheries in the National Forest System. Angling for resident trout in the Siskiyou is minor. The Forest's streams support few fishable populations of resident trout, and only a few small fishing lakes are present. The potential for development or improvement of additional lakes is not great. Clearly, the highest potential for improving fish habitat lies in segments of streams used by anadromous salmonids. Consequently, efforts to improve fish habitat on the Siskiyou were directed first toward eliminating deficits in supply of anadromous salmonids. Improvement of habitat for fall chinook and winter steelhead offers the greatest potential for reduction of deficits.

The capacity of forests in western Oregon to produce resident and anadromous salmonids, as well as other species, varies; regional coordination of proposed projects would in some general way compare expected levels of benefits and costs between Forests. Intraregional coordination of Forest Service projects, and coordination with States and other Federal agencies, should avoid duplication of effort and potential conflicts, as well as direct more funding into the most cost/beneficial areas.

Selecting Projects to Meet Needs

What types of habitat could be improved on the Siskiyou to meet deficits in populations of fall chinook salmon and winter steelhead? To answer this question, factors limiting populations of these species were explored, for both marine and freshwater phases in their life histories. Successful coastwide programs for enhancing hatcheries suggested that the marine environment was not currently limiting any populations of anadromous salmonids produced in southwest Oregon. In fresh water, either spawning or rearing habitat could have been limiting; however, with rare exception, streams on the Siskiyou contained spawning gravels in excess of requirements for seeding the available rearing areas. Increasing spawning gravels would have little or no benefit. Rearing habitat is the limiting factor in most streams on the Forest, primarily because of low streamflows associated with droughty conditions common to southwest Oregon in summer.

What types of projects could most efficiently enhance or expand available rearing areas? Only a few options are available to compensate for shortages of water; a promising one was to allow anadromous salmonids access to unoccupied habitat. Several natural barriers on streams of the Siskiyou block upstream migrants from suitable spawning and rearing habitat. Removing or laddering such barriers could increase production of fall chinook and winter steelhead, and deserved careful study. Program planning started with this type of project but was ultimately expanded to consider all types of projects that could enhance production of anadromous salmonids.

Selecting Geographic Areas for Projects

Other considerations being equal, projects should be located in river basins that have the highest potential to produce additional fish. On the Siskiyou National Forest, the Rogue, Illinois, Chetco, and Elk Rivers probably best fit this category. Projects in those rivers are probably most cost effective—they will probably produce the greatest immediate results (numbers of fish) from funds invested. Potential projects in less productive watersheds, however, should also be considered because the benefits in some, more costly areas could be proportionally much greater than in lower cost areas. Existing data should be compiled for each potential project in which barrier removal or laddering, for example, would benefit anadromous salmonids.

Table 2 — Fish species blocked from upstream access by barriers on Siskiyou National Forest streams

Watershed and streams	Anadromous salmonids Fall chinook	Coho	Summer steelhead	Winter steelhead	Cutthroat
		CHETCO			
Emily	X	X		X	X
Eagle					X
		COQUILLE			
South Fork		X		X	
Elk		X		X	
		ELK			
Anvil		X	X		X
Rock		X	X		X
		ILLINOIS			
Briggs				X	
Cave					X
Collier	X			X	X
Grayback				X	
Indigo	X			X	X
Lawson	X			X	X
Silver	X			X	X
Sucker				X	
		ROGUE			
Burned Timber			X	X	
Shasta Costa	X	X		X	X
Stair					X
		SIXES			
Dry	X	X		X	X

Selecting Project Sites

Inventory data currently available on the Siskiyou list 18 barriers that are restricting upstream access for anadromous salmonids (table 2), but the inventory is incomplete. Additional stream surveys will increase the number of potential projects. Potential sites should be jointly selected by State and Federal agencies.

General Evaluation of Potential Projects

Each site identified is a potential project, but intrinsic or extrinsic factors might preclude its development. Criteria for eliminating projects might include, at least: the species of fish that will benefit; legal constraints; and administrative restrictions on certain projects or geographic areas. This amounts to a simple form of project evaluation that will probably reduce the number of potential projects. Projects not eliminated should be subjected to project planning to determine their priority for development.

Project Planning

The next step in development of a habitat-improvement program is project planning, in which all barriers listed in table 2 would be subjected to an intense analysis of benefits and costs. A natural falls on Shasta Costa Creek in the Rogue Basin illustrates the process of project planning. All barriers in table 2 should be subjected to the same kind of analysis, and ultimately, so should all other potential projects. The focal point of project planning is a feasibility study, which as a minimum includes: an environmental assessment; an engineering investigation; a preliminary design; and a benefit/cost analysis. Four basic areas of project feasibility will be analyzed during the project-planning process — physical, biological, economic, and social.

The economic analysis is the heart of the feasibility study. All costs associated with the project (planning, construction, operation, and maintenance) must be accurately defined over the expected life of the project. Costs can often be identified precisely, but benefits must also be realistically analyzed in detail — and this is perhaps the most difficult aspect of benefit/cost analysis for projects to improve fish and wildlife habitat.

The first step is estimating increased biological production. How many adult fall chinook salmon or winter steelhead will the Shasta Costa project produce? The question is best answered by relating production per unit area below the barrier to comparable spawning and rearing area above the barrier. Laddering will open about 4.76 km of good spawning and rearing habitat for winter steelhead and cutthroat trout, and about 1.60 km for chinook and coho. Stream surveys and redd counts on Shasta Costa Creek indicate that about 43 pairs of steelhead, 13 pairs of fall chinook, 3 pairs of coho, and 12 pairs of cutthroat spawn annually per kilometer of accessible stream. Applying these data to potentially available habitat above the falls, an increased annual escapement of 200 pairs of steelhead, 20 pairs of chinook, 5 pairs of coho, and 60 pairs of cutthroat could be expected to result from laddering. Expected catch of salmon is five times escapement, and expected catch of steelhead and cutthroat from Shasta Costa Creek are 25 and 20 percent of escapement, respectively. No benefits would be realized the first 3 years of the project, and only half the potential annual benefits would be realized during the second 3-year period because of the cyclic life-history patterns of these species. These estimates appear conservative, but we think they are realistic based on observed use of downstream waters.

How can the benefits of increased fish production be estimated? Because benefits are measured by the willingness of people to pay for the change, the effects of the project on anglers, commercial fishers, and others must be estimated. Ideally, commercial fishing benefits attributable to the project would be estimated by the resulting increase in commercial fishing revenues (landed value) minus the resulting increase in commercial fishing costs. Because precise estimates of these revenues, and particularly these costs, are usually not available, average revenues and costs may be substituted. These figures are generally available for major commercial species, and average values probably differ little in the long run from values attributable to the project. If the increase in production is great enough to lower prices, the effects on consumers and producers must be considered. Producers benefit because they harvest more fish with the same effort, and consumers benefit from lower prices at the partial expense of producers. The net benefit may be approximated by multiplying the change in price by the average of total production before the change and total production after the change. Detailed econometric studies would be needed to estimate the benefits more precisely.

Angling benefits are estimated by the willingness of anglers to pay for the change. Because no traditional market for angling exists, however, project planners are often at a loss to estimate such values. Furthermore, if a market existed, the values of improvements in angling would vary greatly from site to site, much more like land values vary from place to place than like the relatively uniform values of commercial fish. The value to anglers of a given increase in fish production depends on the relative change in angling quality, the availability of substitutes similar to preproject and postproject angling quality, the availability of substitute kinds of angling, the preferences of anglers for the preproject and postproject kinds of angling, and the accessibility of the site to anglers. One method of estimating the change in angling value is to ask anglers directly how much they are willing to pay for the change. This method is subject to many pitfalls, however, and is not recommended without guidance from experienced researchers. Angler expenditures are not appropriate measures of project values because they measure the cost of angling rather than anglers' willingness to pay for a project. Willingness to pay for a project is an amount in excess of actual expenditures; it can be thought of as an access fee to use the site. For example, in Great Britain, angling rights are privately owned, and from 1973 to 1976 anglers in Scotland paid an average of $175 per fish to rent a section of river for salmon fishing.

Accurate estimates of angling values in the United States are now possible but expensive, requiring highly sophisticated econometric studies of angler travel and expenditure patterns or of anglers' responses to questions about hypothetical situations. An important caution is necessary here. Unless the study is specific to the project site or a site similar in the five respects mentioned in the previous paragraph, the project values will probably differ from the estimated values. Project value can vary that much, even within a restricted geographic area. In fact, by far most econometric studies of angling values estimate the values of choices that drastically differ from any of the choices usually considered by National Forest planners. Typically the studies estimate the all-or-none value of the fishery investigated — the willingness of anglers to pay to have the present fishery rather than not have it. This is an extreme value, and it is generally higher than most project values because projects on National Forests represent relatively minor changes in the overall fishery. Economists estimate all-or-none values because they are academically interesting and because they represent a clearly identifiable social choice, even if it has practically no direct significance to the projects. More detailed explanations of principles and procedures are available in Clawson and Knetsch (1966), Gregory (1972), and more vigorously in Talhelm (1973), Dwyer et al. (1977), and Freeman (1979).

This leaves the Forest planner with little information on which to estimate project benefits. Even the current values from the Forest and Rangeland Renewable Resources Planning Act used by the Forest Service are based on estimates of all-or-none values. Until better estimates are available, however, project planners have little choice but to follow Forest Service guidelines — as were used for our example, the Shasta Costa project.

Recent National legislation (National Forest Management Act of 1976, P.L. 94-588) requires use of fishery values (and values of other resources) in all land-use plans. The Forest Service, in compliance with P.L. 94-588 and the Forest and Rangeland Renewable Resources Planning Act (RPA), has developed a set of daily consumer benefits (table 3) for use in fishery valuation and economic analysis of habitat-improvement projects (USDA Forest Service 1979).

Table 3 — Net consumer benefits for the USDA Forest Service 1980 Renewable Resources Planning Act Assessment (USDA Forest Service 1979)

Fishery	Consumer benefits/ angler-day	Consumer benefits/ commercial pound
	Dollars	
ANADROMOUS SALMONIDS		
Sport benefits	19.50	—
Commercial benefits	—	0.63
Sport habitat improvement	19.50	—
Commercial habitat improvement	—	0.80
INLAND SPORT FISH		
Cold water/warm water use	5.25	—
Cold water habitat improvement	6.25	—
Warm water habitat improvement	4.25	—

RPA values (table 3) of $19.50 per angler-day for improving habitat for anadromous salmonids and $0.80 per pound for commercially caught salmon were used to estimate consumer benefits for the Shasta Costa project. The procedures are illustrated in figure 1. Most of the predicted net annual benefit of $8,300 is associated with increased production of fall chinook salmon and winter steelhead (table 4). Future evaluations should use the most recent daily consumer benefits recommended by USDA Forest Service. The project will remove about 5.8, 1.5, 10.0, and 8.0 percent, respectively, of the deficit in catch of fall chinook, coho, winter steelhead, and sea-run cutthroat that was expected in southwest Oregon by 1980.

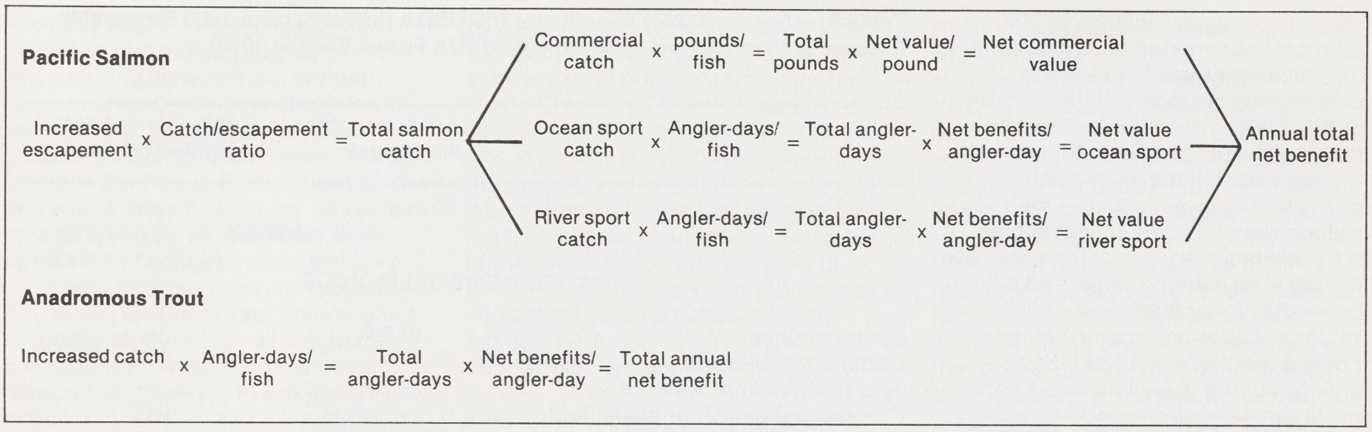


Figure 1. — Procedures for evaluating increased production of Pacific salmon and anadromous trout resulting from habitat improvement.

Table 4 — Expected annual net economic benefits from laddering a natural barrier on Shasta Costa Creek, Siskiyou National Forest

Species	Increased catch	Net consumer benefits, sport	Net consumer benefits, commercial	Total net consumer benefits	"Catch deficit" relieved
	Number	*Dollars*			
Fall chinook	200	1,360	1,210	2,570	5.8
Coho	50	330	190	520	1.5
Winter steelhead	100	4,680	—	4,680	10.0
Cutthroat	24	530	—	530	8.0
Total	374	6,900	1,400	8,300	

Costs associated with the project were also estimated. The Shasta Costa barrier, located 2 km from the nearest access road, is composed of a formation of bedrock and large boulders that creates a cascade about 3.2 m high. A concrete fishway, an aluminum Alaska steeppass, and a bedrock fishway created by blasting were considered possible alternatives for upstream passage of salmonids. Estimated construction costs of a conventional concrete fishway at this remote location exceeded $100,000, and the cost of a steeppass was about $25,000. Steeppasses, however, are easily clogged with debris and need frequent attention during freshets — a major disadvantage in a remote location. A fishway constructed by drilling, blasting, and adding minor supplemental weirs of concrete and reinforcing steel was easy to build at this location, economical, and required little maintenance. The estimated cost included $930 for planning, $9,170 for construction, and $300 annually for maintenance (table 5). Because anticipated benefits were the same for all three construction techniques, the third alternative was selected.

Once costs and benefits have been estimated, project alternatives may be compared. Costs and benefits anticipated during the effective life of the project (considered to be 20 years in this example) may be listed in a table and discounted back to a common time, usually the year of construction. Discounting is necessary because a dollar today is worth more than the prospect of a dollar at some future date, and discounting determines the present worth of costs and benefits that are incurred or realized in the future. The present worth (discounted value) of a cost incurred in the future is calculated by use of the single-payment, present-worth factor by the formula:

$$P = S \frac{1}{(1 + i)^n},$$

where P = worth of the sum S, n years in the future at interest rate i. For example, the present worth of a $500 benefit expected 2 years in the future at 7-percent interest equals:

$$P = 500 \frac{1}{(1 + 0.07)^2} = \$437.$$

For a more detailed discussion of discounting, see Sheridan (1969) and Grant and Ireson (1970). A planner should use this standard method of discounting and the appropriate current interest rate to estimate present worth of project costs and benefits. In this example, we have used an interest rate of 7 percent as recommended by the Water Resources Council (1973) for water-related development projects (table 6). The benefit/cost ratio (B/C) was derived by dividing discounted benefits by discounted costs. If the ratio is greater than 1, the project is economically sound. The Shasta Costa project, with a ratio of 4.33:1, appeared to be economically sound and highly desirable for development.

Table 5 — Estimated costs of providing fish passage at a natural barrier on Shasta Costa Creek, Siskiyou National Forest

Activity	Cost
PROGRAM PLANNING	*Dollars*
1 person-day	80
PROJECT PLANNING	
11 person-days	750
Travel	100
CONSTRUCTION	
40 person-days	3,500
Travel and per diem	800
Powder	120
Concrete, steel, wood	500
Equipment	3,000
Helicopter time	750
Administration	500
Maintenance, $300 annually	5,700
Total	15,800

If a project B/C ratio is sensitive to changes in interest rates or to errors in estimated costs and benefits, especially if the ratio is near 1:1, the project is considered risky. For example, the Office of Management and Budget (OMB) requires that economic soundness of projects to improve fish habitat considered by the USDA Forest Service be assessed at a 10-percent discount rate. If a slight increase in interest rate changes the B/C ratio from a number greater than one (>1) to a number less than one (<1), the project might be questionable. To test its sensitivity to errors in cost and benefit measurement, the B/C ratio could be recalculated, for example, with the assumption that costs are up 10 percent and benefits are down 10 percent. If slight changes in benefits and costs change the B/C ratio from a number >1 to a number <1, the project might be marginal. Sensitivity analysis is highly recommended because estimates of project benefits are so uncertain.

Table 6 — Discounted benefits and costs of the Shasta Costa project, Siskiyou National Forest, and benefit/cost ratio calculated at a discount rate of 7 percent

Year	Cost	Discounted cost	Benefit	Discounted benefit[1]	Discount factor @ .07
			Dollars		
1	10,100	10,100	0	0	.9346
2	300	280	0	0	.8734
3	300	262	0	0	.8163
4	300	245	4,150	3,166	.7629
5	300	229	4,150	2,959	.7130
6	300	214	4,150	2,765	.6663
7	300	200	8,300	5,168	.6227
8	300	187	8,300	4,831	.5820
9	300	175	8,300	4,514	.5439
10	300	163	8,300	4,219	.5083
11	300	152	8,300	3,943	.4751
12	300	143	8,300	3,685	.4400
13	300	133	8,300	3,445	.4150
14	300	125	8,300	3,219	.3878
15	300	116	8,300	3,008	.3624
16	300	109	8,300	2,811	.3387
17	300	102	8,300	2,628	.3166
18	300	95	8,300	2,456	.2959
19	300	89	8,300	2,295	.2765
20	300	83	8,300	2,115	.2584
Total	15,800	13,202	128,650	57,227	

$$B/C = \frac{57,227}{13,202} = 4.33$$

[1] Costs are not discounted in year 1, but any benefits realized in year 1 are discounted.

The B/C ratio can be calculated perhaps most efficiently by using the USDA Forest Service, California Region (R-5) computer program, Invest III (USDA Forest Service 1972). The program allows use of three interest rates in determining B/C ratios and has internal provisions for testing sensitivity to changes in anticipated benefits and costs. Invest III sensitivity analysis for the Shasta Costa project indicated that the positive B/C ratio of 4.33 at 7-percent interest is not sensitive to slight changes in interest rate or costs and benefits. If costs are increased 10 percent and benefits reduced 10 percent, the B/C ratio is still a positive 3.55:1. At the OMB-recommended interest rate of 10 percent, the B/C is 3.35:1 and at 6 percent, 4.47:1. Invest III also estimates present net worth at three interest rates and the internal rate of return. The present net worth of the Shasta Costa project are $29,658, $44,057, and $50,253, respectively, at 10-, 7-, and 6-percent interest, and the internal rate of return is 26.6 percent. Figures 2 and 3 list Invest III data for the Shasta Costa project. For detailed information on Invest III, consult R-5 Invest III handbook (USDA Forest Service 1972).

The internal rate of return (IRR) assesses the relative payoff of a project. If a limited budget is available and projects being considered range greatly in size, the easiest way to select the group of projects with the greatest aggregate return within the budget is to compare internal rates of return. Simply rank projects by IRR, and choose the highest set possible within the budget.

Public review is often the final step in determining the soundness of a project. After physical, biological, and economic analyses are complete, an environmental analysis or an environmental impact statement must be written. If a project has a significant impact on the environment, it must have public review. Negative public response could result in a decision to defer or delete the project from further consideration. If the project survives public review, it is ready to be undertaken when funds become available.

For a complete analysis of improvement projects associated with barriers, other potential projects listed in table 2 should be subjected to the planning process. Detailed B/C and IRR analyses of each project should determine priority. Also, because habitat inventory on the Siskiyou is incomplete, the planning process must be kept open to accommodate new information as it is collected.

CARD TYPE	ALT. NO.	BASE NO.	NAME OF FOREST ORGANIZATION
			NAME OF UNIT
			NAME OF USER
			NAME OF PROBLEM
			PROBLEM DESCRIPTION

LONG-TERM INVESTMENT ANALYSIS

BENEFIT AND COST EFFECTIVENESS COMPARISON
(SEE INVEST III FAST VERSION USER GUIDE)

OMB RATE	OPT RATE	RANK RATE

CARD TYPE	ALT. NO.	BASE NO.	SEQ. NO.	ITEM DESCRIPTION	PMT TYPE	YEAR	YEAR	TOTAL AREA	UNITS	COST OR INCOME DOLLARS

CARD TYPE	ALT. NO.	BASE NO.	NAME OF FOREST ORGANIZATION
1		100	SISKIYOU NATIONAL FOREST
2		100	NAME OF UNIT FISH AND WILDLIFE
3		100	NAME OF USER EVEREST
4		100	NAME OF PROBLEM SHASTA COSTA BARRIER 100
5		100	PROBLEM DESCRIPTION SHASTA COSTA FISH PASSAGE FACILITY

LONG-TERM INVESTMENT ANALYSIS

BENEFIT AND COST EFFECTIVENESS COMPARISON
(SEE INVEST III FAST VERSION USER GUIDE)

OMB RATE	OPT RATE	RANK RATE
1000	0700	0700

CARD TYPE	ALT. NO.	BASE NO.	SEQ. NO.	ITEM DESCRIPTION	PMT TYPE	YEAR	YEAR	TOTAL AREA	UNITS	COST OR INCOME DOLLARS
6			1	1 CONSTRUCTION	01	000	001			-10,100
6			2	1 MAINTENANCE	02	002	020			-300
6			3	1 NET FISH BENEFITS	02	004	006			4,150
6			4	1 NET FISH BENEFITS	02	007	020			8,300
7		100	1							.10
7		100	2							.10
7		100	3							-.10
7		100	4							-.10

Figure 2. — Standard Invest III (USDA Forest Service 1972) form for benefit/cost analysis. Data are for the Shasta Costa project, Siskiyou National Forest.

Figure 3. — Simulated Invest III output data for benefit/cost analysis of the Shasta Costa project.

Project Evaluation

The final element in program development — perhaps equal in importance to the steps discussed previously — is postdevelopment assessment of the accuracy of the cost and benefit estimates. Long-term projects may be assessed several times over their lives.

The Shasta Costa fishway construction was completed in 1978. Actual construction costs were $1,384 higher than estimated. The annual maintenance fee of $300/year is still anticipated to be correct. Increases in fish production cannot yet be measured, but the fishway is allowing fall chinook salmon and winter steelhead to pass upstream, and projected increases in production will probably occur. Based on the increase in construction costs and the probability that anticipated benefits will be realized, a postconstruction benefit/cost ratio (3.92:1) can be calculated at a 7-percent discount rate. Additional benefit/cost calculations should be made as actual increases in biological production are monitored over the next few years. Results of such evaluations are valuable in planning future projects to enhance habitat and improving precision of future benefit/cost analyses.

Literature Cited

Clawson, Marion; Knetsch, Jack. Economics of outdoor recreation. Baltimore: Johns Hopkins University Press; 1966.

Dwyer, John F.; Kelly, John R.; Bowes, Michael D. Improved procedures for valuation of the contribution of recreation to national economic development. University of Illinois, Water Resources Center, Urbana-Champaign; 1977. 219 p.

Francis, George R.; Magnuson, John J.; Regier, Henry A.; Talhelm, Daniel R. Rehabilitating Great Lakes ecosystems. Tech. Rep. 37. Ann Arbor, MI: Great Lakes Fishery Commission; 1979. 99 p.

Freeman, A. Murick, III. The benefits of environmental improvement: theory and practice. Baltimore: Johns Hopkins University Press; 1979.

Grant, E.; Ireson, W.G. Principles of engineering economy. New York: Ronald Press Co.; 1970. 640 p.

Gregory, G. Robinson. Forest economics. New York: Ronald Press Co.; 1972. 548 p.

Sheridan, W.L. Benefit/cost analysis of salmon habitat improvement in the Alaska region. Juneau, AK: U.S. Department of Agriculture, Forest Service, Alaska Region; 1969. 47 p.

Talhelm, Daniel R. Defining and evaluating recreation quality. Trans. 38th North Am. Wildl. and Nat. Resour. Conf. 38: 183-191; 1973.

Talhelm, Daniel R. Defining angling supply: the key to recreational fishery resource evaluation. In: Proceedings, International symposium on fishery resource allocation. Vichy, France: European Inland Fisheries Advisory Commission; 1980. 18 p.

U.S. Department of Agriculture, Forest Service. Invest III; A benefit/cost program for quantitatively examining alternative resource programs. San Francisco, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region; 1972. 40 p.

U.S. Department of Agriculture, Forest Service. A statewide comprehensive plan for fish and wildlife on the National Forests of Oregon. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1976. 15 p.

U.S. Department of Agriculture, Forest Service. 1980 RPA values. Washington, D.C.: U.S. Department of Agriculture, Forest Service; 1979. 48 p.

Water Resources Council. Water and related land resources, establishment of principles and standards for planning. Fed. Regist. 38(174): 1-167; 1973. Part III.

Everest, Fred H.; Talhelm, Daniel R. Evaluating projects for improving fish and wildlife habitat on National Forests. Gen. Tech. Rep. PNW-146. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982. 12 p.

Recent legislation (P.L. 93-452; P.L. 94-588) has emphasized improvement of fish and wildlife habitat on lands of the National Forest System. A sequential procedure has been developed for screening potential projects to identify those producing the greatest fishery benefits. The procedure — which includes program planning, project planning, and intensive benefit/cost analysis — has nationwide application for both fish and wildlife projects. Fisheries and wildlife values are difficult to assess and available estimates are far from ideal, but better estimates are gradually becoming available.

Keywords: Habitat improvement, wildlife habitat, cost/benefit evaluation, program planning, salmonids.

Pacific Northwest Forest and Range
Experiment Station
809 NE Sixth Avenue
Portland, Oregon 97232

Northeast Gulf Science Vol. 6. No. 2, p. 109-120 October 1983

TROPHIC RELATIONSHIPS OF FISHES OCCURRING WITHIN A SURF ZONE HABITAT IN THE NORTHERN GULF OF MEXICO

Timothy Modde[1] and Stephen T. Ross[2]
Department of Biology, Box 5018
University of Southern Mississippi
Hattiesburg, MS 39401

Abstract: We studied trophic relationships of Florida pompano (*Trachinotus carolinus*), gulf kingfish (*Menticirrhus littoralis*), scaled sardine (*Harengula jaguana*), striped anchovy (*Anchoa hepsetus*) and dusky anchovy (*A. lyolepis*) during their spring residency in the Horn Island, Mississippi, surf zone. *Harengula jaguana, A. lyolepis* and *A. hepsetus* were zooplanktivores, utilizing primarily calanoid copepods, mysids and various decapod larvae. *Menticirrhus littoralis* and *T. carolinus* utilized benthic prey including *Donax, Emerita* and polychaetes; however, small pompano also fed on zooplankton. *Menticirrhus littoralis, T. carolinus, H. jaguana* and *A. lyolepis* also showed distinct dietary changes with increasing fish size. Three species, *A. lyolepis, H. jaguana* and *M. littoralis* fed at least partially at night, while *T. carolinus* and *A. hepsetus* were primarily diurnal predators. Cluster analysis of size intervals of all species based on presence or absence of prey taxa formed groups consistent with taxonomic relationships, thus indicating considerable interspecific resource separation.

INTRODUCTION

Surf zone regions of the Gulf of Mexico are important habitats for the juvenile stages of many fishes (Gunter 1958; Springer and Woodburn 1960; Naughton and Saloman 1978; McMichael and Ross 1980; Modde 1980; Modde and Ross 1981). In general, young fishes occur in surf zones during the spring and summer, although fall and winter spawned species such as *Lagodon rhomboides, Leiostomus xanthurus, Mugil cephalus,* or *Brevoortia patronus* may occupy them during winter and early spring (Modde and Ross 1981). In addition to seasonal periodicity, fishes show diel utilization patterns of surf zones, with the greatest abundance occurring in the early morning (Modde and Ross 1981). Thus, the surf zone, in addition to being a physically dynamic habitat, is characterized by a dynamic ichthyofauna in which different suites of species may be interacting daily and seasonally.

Trophic relationships of fishes in surf zone areas are largely unknown even though many species, such as pompano (*Trachinotus carolinus*), gulf kingfish (*Menticirrhus littoralis*), scaled sardine (*Harengula jaguana*), and mullet (*Mugil* spp.) are of commercial importance. Thus, the purpose of our study was to compare food habits and relationships of the numerically dominant spring-summer fishes of the Horn Island, Mississippi, surf zone. Species selected for analysis were: *Anchoa lyolepis* (dusky anchovy), *A. hepsetus* (striped anchovy), *Harengula jaguana* (scaled sardine), *Trachinotus carolinus* (Florida pompano), and (*Menticirrhus littoralis* (gulf kingfish).

METHODS AND MATERIALS

Sampling stations were in the surf zone habitat along the windward shore of Horn Island, Jackson County, Mississippi. Horn Island is one of a chain

---

[1] Present address: Department of Wildlife and Fisheries Sciences, South Dakota State University, Brookings, SD 57007.

[2] Visiting Research Professor (1981-1982) University of Oklahoma, Biological Station, Star Rt. B, Kingston, OK 73439.

of barrier islands lying parallel to the Mississippi-Alabama Gulf coast (Fig. 1). The island is approximately 14 km offshore, 19 km long and less than 1.2 km wide. The center of the island is at 30° 14″ N and 88° 40′ W (Franks 1970). The windward beach is partially protected from oceanic wind driven waves by a series of sand bars which extend the length of the island. The exposed beach is characterized by a sand substrate, moderate wave activity, and the absence of any rooted vegetation. The four stations (Fig. 1) were located within an environment categorized by Odum and Copeland (1974) as a high energy beach system.

Fishes were collected with a 9.1 x 1.8 m bag seine with 3.2 mm mesh. The net was hauled perpendicular to the beach face, beginning 16-18 m offshore. The sampled area was from the swash zone to the midlongshore trough and included only areas exposed directly to surf. Five to nine seine hauls were taken at each location between 0900 and 1500 CST (see also Modde and Ross 1981).

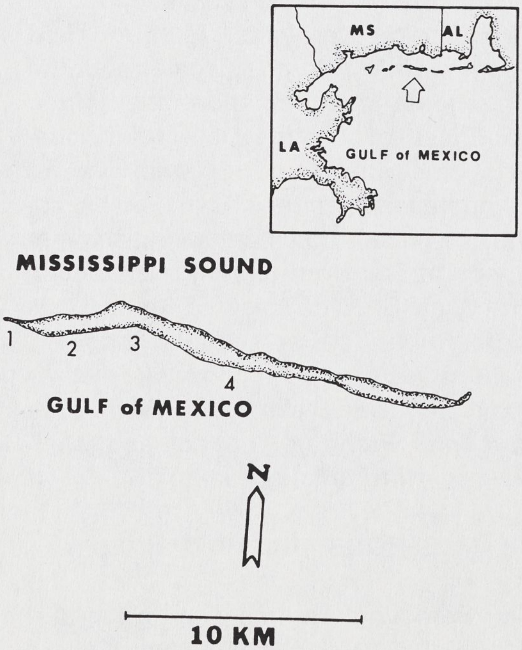


Figure 1. Map of the study area on Horn Island, Jackson County, Mississippi.

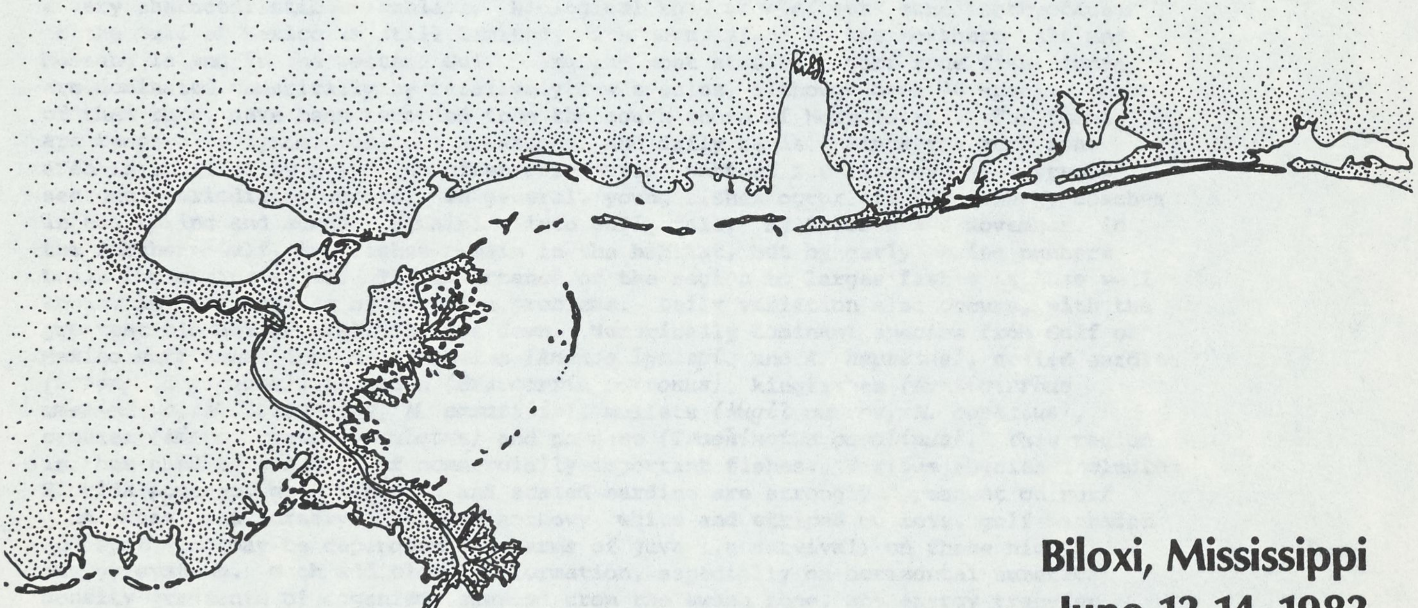
Stomach contents of *M. littoralis* and *H. jaguana* were examined for May (N = 45, 181), June (N = 11, 85) and July (N = 37, 59). Stomach contents of *T. carolinus* were analyzed for May (N = 150) and June (N = 28), while stomachs of *A. hepsetus* were examined only for May (N = 127). Stomach contents of *A. lyolepis* were studied in May (N = 51) and September (N = 101). The September data were included due to better representation of fish within most time periods. The duration for which stomachs were collected for the different species was dependent upon the occurrence of fishes in the surf zone for the spring and summer of 1976.

Every month between March-September 1976 (excluding August) we sampled either Station 1, 3 or 4 over a 24 h period, taking samples at approximately 4 h intervals. The choice of station was based in part on the availability of a safe anchorage for our boat.

Immediately upon capture, fishes were placed in MS 222 to prevent regurgitation and then fixed in 10% Formalin. Stomach content analysis included identification, determination of volume and percent occurrence of prey items within the stomachs. The section of the alimentary tract examined was that anterior to the pyloric sphincter. We determined the volume of food organisms smaller than .05 cc by a squash technique modified from Hellawell and Abel (1971) by Ross (1974), and the volume of larger food items by displacement.

Plots of cumulative taxa versus the number of stomachs examined indicated that sample sizes sufficient for description of prey kind were obtained for all length groups with the exception of the proceedings of the

Northern Gulf of Mexico Estuaries and Barrier Islands Research Conference



Biloxi, Mississippi
June 13-14, 1983

Sponsored by:

NATIONAL PARK SERVICE
MISSISSIPPI BUREAU OF MARINE RESOURCES
GULF COAST RESEARCH LABORATORY
MISSISSIPPI COOPERATIVE EXTENSION SERVICE

These Proceedings should be cited as follows:

Shabica, S. V., N. B. Cofer & E. W. Cake, Jr., eds. 1983. *Proceedings of the northern Gulf of Mexico estuaries and barrier islands research conference.* 13–14 June 1983, Biloxi, MS. U.S. Dep. Int. Natl. Park Serv. SE Reg. Off., Atlanta, GA. 191 pp.

A REVIEW OF SURF ZONE ICHTHYOFAUNAS IN THE GULF OF MEXICO

Stephen T. Ross
Department of Biological Sciences
University of Southern Mississippi
Hattiesburg, MS 39406-5018

ABSTRACT: High energy surf zone habitats bordering the Gulf of Mexico provide an important resource, from both a recreational and biological perspective. Because of the overriding effect of high wind-driven wave energy, such areas show well defined physical characteristics and form a broad filtration system, removing detrital and planktonic components from the water column and concentrating nutrients along the swash zone. Organisms capable of utilizing these regions often show high degrees of morphological, physiological or behavioral specialization and form a very characteristic assemblage. Biological knowledge of surf zone ichthyofaunas in the Gulf of Mexico is still limited, with Horn Island in the northern Gulf and Mustang Island in the western Gulf being the most studied. Surf zone fish faunas are dominated numerically by relatively few species, although over 76 species, most of them rare, have been recorded from the south shore of Horn Island. The faunas are temporally dynamic on both a seasonal and daily basis. Since the surf zone area is utilized by a species often only during part of its life cycle, a strong seasonal periodicity occurs. In general, young fishes occur off high energy beaches in the spring and summer, remaining into early fall. By October and November, in the Northern Gulf, few fishes remain in the habitat, but by early spring numbers begin increasing again. The importance of the region to larger fishes is less well known, in part because of sampling problems. Daily variation also occurs, with the greatest biomass generally before dawn. Numerically dominant species from Gulf of Mexico surf zones include anchovies *(Anchoa lyolepis* and *A. hepsetus)*, scaled sardine *(Harengula jaguana)*, menhaden *(Brevoortia patronus)*, kingfishes *(Menticirrhus americanus, M. littoralis, M. saxatilis)*, mullets *(Mugil curema, M. cephalus)*, croaker *(Micropogonias undulatus)* and pompano *(Trachinotus carolinus)*. This region is thus used by a number of commercially important fishes. Various species including Florida pompano, gulf kingfish and scaled sardine are strongly dependent on surf zone areas as a nursery. Striped anchovy, white and striped mullets, gulf menhaden and spot also may be dependent (in terms of juvenile survival) on these high energy systems. Much additional information, especially on horizontal numerical density gradients of organisms seaward from the swash zone, and energy transfer in the surf ecosystem, is needed. It is important to emphasize, however, that the value of a habitat to a species should not be judged solely by the duration that an organism occupies it, but by how critical a role the habitat plays in the life cycle of the species. Temporally dynamic surf zones utilized by various fishes and invertebrates, especially during portions of their early life history, may have a much greater role in the life cycles of the coastal organisms than previously realized.

INTRODUCTION

High energy beaches form an extensive but discontinuous border around the Gulf of Mexico, occurring along mainland coasts as well as on barrier islands. Barrier island beaches are significant, comprising 26% of the linear coastal beach system in Alabama and 39% in Mississippi (Taylor et al. 1973). The coastline of the western Gulf of Mexico is bordered by extensive barrier islands also (Hill and Hunter 1976).

The purpose of this paper is to review studies of fish assemblages occurring off high energy beaches in the Gulf of Mexico, with emphasis on the northern Gulf, and to relate this information to our understanding of the coastal ecosystems in general. In any review such as this, geographic level differences affect one's ability to make generalizations. However, since high energy beach systems are united by well defined physical characteristics caused primarily by wave action, it may be less difficult to make generalizations for these habitats compared to other marine or estuarine areas. The scope of the habitat sampled in the various studies, while variable, has usually included the surf (strictly defined), the transition, and swash zones (Fig. 1). For the purpose of this paper I will use the term surf zone in the broad sense (cf. McLachlan et al. 1981a) covering the habitat from the breaker zone to the water's edge at the swash zone. The terminology for beaches follows

McLachlan (1980b) where exposed beaches are those experiencing moderate to heavy wave action, having the reduced layers deep, and generally lacking macrofaunal burrows.

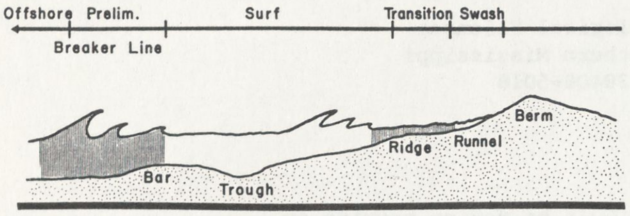


Fig. 1. A diagrammatic representation of the near-shore, open beach habitat. Hatched areas indicate regions of higher wave energy. Modified from Ingle (1966 and Schiffman 1965).

High energy beach systems, characterized by pounding surf and a shifting sand substrate, offer a particularly harsh environment to living organisms. Hedgpeth (1957) considered such areas to be less favorable for life than other shore habitats, except gravel or cobble beaches. Because of the harshness, high energy beach systems support a specifically adapted invertebrate (e.g. Dahl 1952; Riedl and McMahan 1974; Diaz 1980; Dye et al. 1981) and vertebrate (e.g. Gunter 1958; McFarland 1963b; Anderson et al. 1977; Modde and Ross 1981) fauna. However, to species adapted to this environment, the wave energy may provide a considerable advantage. For instance, species of the mole crab *(Emerita)* depend on water currents generated by receding waves for nutrition. Mole crabs feed on plankton and detritus by filtering the backwash from waves with their plumose antennae (Dahl 1952; Efford 1966; Ansell et al. 1972; Leber 1982). The often abundant haustorid amphipods may have similar ecological roles (Dahl 1952; Dexter 1969). Wave energy supplies plankton and detritus to the filter feeding bivalve *Donax*, as well as facilitating horizontal movement by physical displacement (Wade 1967). Wave energy is also likely exploited by fishes in exposing prey and in concentrating plankton along the swash zone.

Beaches operate as large filtration systems along the swash zone and thus carry out an invaluable role as biological purification systems for coastal water. Riedl (1971) estimated that an average beach would filter approximately 10 m^3 m^{-1} beach per day, and McLachlan (1979) determined filtration rates of 3.8 to 15.2 m^3 m^{-1} per day. Filtration is positively related to beach slope, tidal range, substrate particle size and exposure, and inversely related to wave frequency (McLachlan 1979; 1982).

Pearse, Humm and Wharton (1942) provided one of the first studies on high energy beach ecosystems. One of their conclusions identified the importance of sand beaches as great digestive and incubating systems in which bacteria break down organic remains providing a supply of inorganic nutrients to the surrounding water. Bacterial concentrations in high energy beaches can be substantial. For example, Meyer-Reil et al. (1978) determined an average total bacterial biomass of 5.0 g dry weight per m^2 of beach (taken to a depth of 10 cm) for surf zones of the Baltic Sea.

Recent studies of McLachlan (1980a) and McLachlan et al. (1981a) indicate that surf zones, from the intertidal and subtidal areas to the perimeter of the surf cells, form a functional ecosystem. The argument for this is that the amount of inorganic nutrient material liberated in the surf zone through the mineralizing activity of the interstitial microfauna and macrofauna is sufficient to support local plankton blooms. Because surf zone areas often have a cellular circulation sufficient to retain nutrients long enough for plankton blooms to occur, the beach system may be only slightly subsidized with the bulk of the energy turnover occurring within the system. The degree of subsidy likely varies between different beaches and seasons, in part through the differential importation of particulate organic material, carrion (McLachlan et al. 1981a) and fish feces. Whether surf zones of the Gulf of Mexico constitute semi-enclosed ecosystems is not known; however, the conclusion gains support by work of McFarland (1963a) who suggested that net primary production in the surf zone of Mustang Island may be able to maintain the entire heterotrophic component of the zone during the summer. Gunter (1979) also reported localized plankton blooms off Texas beaches, again suggesting the localized release and retention of nutrients in the surf zone.

Primary production in surf zones is accomished essentially by phytoplankton. For instance, Ansell et al. (1972) found that Indian beaches had essentially no primary production by interstitial or attached micro-organisms. Instead, surf zone organisms were dependent on the water overlying the sand for food requirements, through primary production, detrital input or carrion. Phytoplankton production varies seasonally. McFarland (1963a) found that plankton metabolism paralleled fish abundance, being higher in summer and lower in the winter for the surf zone of Mustang Island, Texas. Carrion importation, while non-predictable, may at times provide substantial energy subsidies as well (Brown 1964; Gunter 1979). Lenanton et al. (1982) have recently shown that detached plants washed into surf zones may harbor an invertebrate fauna, especially amphipods, which constitute an important element in the diet of some Australian surf zone fishes. The dominant macrofaunal invertebrates in surf zone areas are detrital feeders (primarily deposit feeders) (Hill and Hunter 1976) or planktivores (McLachlan et al. 1981b; Shelton and Robertson 1981).

Gunter (1958) commented that "Vertebrate life of the beach environment is little known." Today, such a statement largely remains true for most surf zone systems in North America, including the Gulf of Mexico. For instance, Bagur (1978), in an annotated bibliography of United States barrier islands, listed only two studies dealing with fishes from surf zone areas of

Gulf of Mexico barrier islands, yet the outer beaches of barrier islands form an extensive border around the Gulf. More recently, Modde (1980), Modde and Ross (1981), McMichael (1981), Modde and Ross (1983), Ruple (1983), McMichael and Ross (in prep.) and Ross et al. (in prep.) have examined various aspects of the ichthyofauna associated with the Horn Island, Mississippi surf zone. In addition, Shelton and Robertson (1981) studied macroinvertebrate assemblages along two high energy beach systems in the northern Gulf of Mexico off of Texas, and Naughton and Saloman (1978), and Saloman and Naughton (1978; 1979) studied fishes and invertebrates from the swash zone of Panama City Beach, and fishes from Pinellas County beaches in Florida. The only other high energy beach system well studied in regard to fishes in the entire Gulf of Mexico is Mustang Island, Texas (Gunter 1945; 1958; McFarland 1963b).

While many high energy beaches in the Gulf of Mexico remain to be studied, I believe it timely and important to review what is known about surf zone ichthyofaunas. The outer beaches are the first line of defense against coastal storms (Nummedal 1982), but they are also the coastal environment first in line of impact from offshore pollution. Surf zone areas may be one of the most sensitive regions of the coastal environment, but their dynamic nature makes detection of man-made perturbation difficult (Dye 1981; McLachlan et al. 1981b). Because general knowledge of the northern Gulf of Mexico is limited, this review should help provide coastal planners and fisheries managers with the necessary information to make educated decisions concerning management of high energy beach systems, and species utilizing them.

FISHES

Species Composition

Surf zone fish faunas are characterized by relatively few species making up the majority of individuals. In the Gulf of Mexico between 4-10 species comprised 90% of the individuals collected (Table 1). The same pattern is true for the Atlantic coast of the United States as Anderson et al. (1977) found that five fish species comprised over 90% of the specimens collected from Folley Beach, North Carolina and Schaefer (1967) reported that less than ten species comprised 90% of the catch from a Long Island beach over a three year period. The data for biomass are much more limited, but suggest for both Mustang and Horn island surf zones a somewhat more even distribution between species, with 13 and 16 species, respectively, making up 90% of the biomass. Anderson et al. (1977) found that five species of fishes only made up 69% of the biomass of the Folley Beach surf zone, again indicating a greater evenness.

The total number of fish species reported from Gulf of Mexico surf zones ranges between 44-76, with a strong mode in the 40's (Table 1). The higher species number reported by Modde and Ross (1981) is likely due to more months being sampled as well as the small mesh size used. In fact, there is a significant relationship between the number of species collected and the number of months sampled ($r_s = .86, P < .01$) for the available studies (Table 1). The Spearman rank correlation statistic (r_s) was calculated following Siegel (1956) after correcting for ties. The greatest decline in species versus sampling effort occurs in studies of less than eleven months. In addition to sampling effort, comparison of species numbers between studies is complicated by differences in technique, sampling efficiency of gear (including mesh size and net dimensions), and timing, both seasonal and diel, of the sampling.

Various authors, including Gunter (1958), McFarland (1963b), and Modde and Ross (1981) have commented on the apparent high faunal similarity of surf zone ichthyofaunas from different areas. This is of course especially true for comparisons within a single geographic region. A listing of the eight most abundant species reported from the Gulf of Mexico surf zones certainly supports the statement of high faunal similarity (Fig. 2). Fishes broadly characteristic (based on number) of high energy beach areas include scaled sardines *(Harengula jaguana)*, gulf menhaden *(Brevoortia patronus)*, bay anchovies *(Anchoa mitchilli)*, dusky anchovies *(A. lyolepis)*, striped anchovies *(A. hepsetus)*, sea catfish *(Arius felis)*, Atlantic threadfin *(Polydactylus octonemus)*, silversides *(Menidia peninsulae* and *M. beryllina)*, white mullet *(Mugil curema)*, Florida pompano *(Trachinotus carolinus)*, Atlantic bumper *(Chloroscombrus chrysurus)*, Atlantic croaker *(Micropogonias undulatus)*, gulf kingfish *(Menticirrhus littoralis)*, and pinfish *(Lagodon rhomboides)*. The studies used in Fig. 2 did not address larval fishes and are also likely biased in varying degrees against larger fishes that may escape from small seines. Two studies cited in Table 1, McFarland (1963b) and Ross et al. (in prep.) partially controlled for escapement of larger fishes by using longer seines (cf. Table 1). Only Ruple (1983) (not listed in Table 1), has studied larval fishes.

The 69 species of larval fishes recorded by Ruple (1983) from the Horn Island surf zone is very similar to the number of species represented by juvenile and adult individuals for Horn Island (cf. Table 1). However, species composition of larvae differed from juvenile and adult fishes. Five taxa, *Bairdiella chrysoura, Trinectes maculatus, Dormitator maculatus, Gobionellus* spp. and *Myrophis punctatus* were common as larvae but were rarely collected as juveniles or adults. Conversely, *H. jaguana, T. carolinus* and *M. littoralis*, common as juveniles or adults, were rarely collected as larvae. Species numerically dominant as juveniles and adults, which were also listed by Ruple (1983) as being dominant as larvae, include engraulids, spot, gulf menhaden and pinfish. Thus, for some fish species the surf zone environment is used only by larval stages with the juvenile nursery ground located elsewhere, primarily in lower salinity environments. For the second group, spawning occurs further offshore (Ruple 1983) so that the surf zone is not encountered until the larval stage is near completion. The surf zone functions as a nursery for the juvenile stage of these species. The third group apparently spawns in both nearshore as well as more offshore waters (Ruple 1983), but reaches the barrier island surf zone as larvae and remains in the area as juveniles or even adults.

Only several Gulf of Mexico studies have evaluated the biomass of fishes in surf zone habitats. McFarland (1963b) reported a very similar ranking of species importance for both number and biomass, with the five numerically dominant species included within the top eight in importance based on biomass. Ross et al. (in prep.) in contrast, found more of a difference as only four of the top five species based on number were included in the upper 10 based on biomass. The primary reason for this is the use of a much smaller mesh size in the latter study resulting in the retention of numerous early juvenile stages of many species. The eight most important species from Horn Island, based on biomass, were striped mullet, sheepshead, sea catfish, spadefish, gulf kingfish, scaled sardine, bluntnose stingray and pinfish.

The zonation of fishes in surf zone environments is also likely important, both in abundance and species composition. Ruple (1983) for instance, found differences in both number and kind of larval fishes in the inner and outer areas of the Horn Island surf zone with more larvae being collected in the outer surf areas. Juvenile kingfish seem most abundant within the swash zone (pers.obs.). However, there is little additional information on species zonation, in part due to the

Table 1. Species numbers and abundance of numerically and gravimetrically dominant fish species reported from surf zone environments in the Gulf of Mexico. (S = stretched mesh; B = bar mesh)

Total Species	Species Comprising 90% Number	Species Comprising 90% Weight	Location	Number of Sample Months	Gear Size Length	Mesh	Source
-	6	-	Mustang Island, Texas	16	15.2m	8.4mm-S	Gunter 1945
44	8	-	Mustang Island, Texas	11	15.2m	6.4-8.4 mm-S	Gunter 1958
47	10	13	Mustang Island, Texas	11	193m	19mm-S	McFarland 1963b
25	5	-	Gilchrist, Texas	2	30.5m	19mm-S	Reid 1955a;b
38	8*	-	Gilchrist, Texas	1	30.5m	19mm-S	Reid 1956
76	5	-	Horn Island, Mississippi	21	9.1m	3.2mm-B	Modde & Ross 1981
57	6	16	Horn Island, Mississippi	12	50m	3.2mm-B	Ross et al. in prep.
44	6	-	Panama City, Florida	12	30.5m	6.4mm-B	Naughton & Saloman 1978
48	-	-	Passe-a-Grille & Bella Vista Beaches, Pinellas Co., Florida	14	15.2m	9.5mm-S	Springer & Woodburn 1960
62	5	-	Barrier Island Beaches, Pinellas Co., Florida	12	30.5m	6.4mm-B	Saloman & Naughton 1979
22	7	-	Sanibel Island, Florida	10	30.5m	6.3mm	Gunter & Hall 1965

* comprised 97% of catch

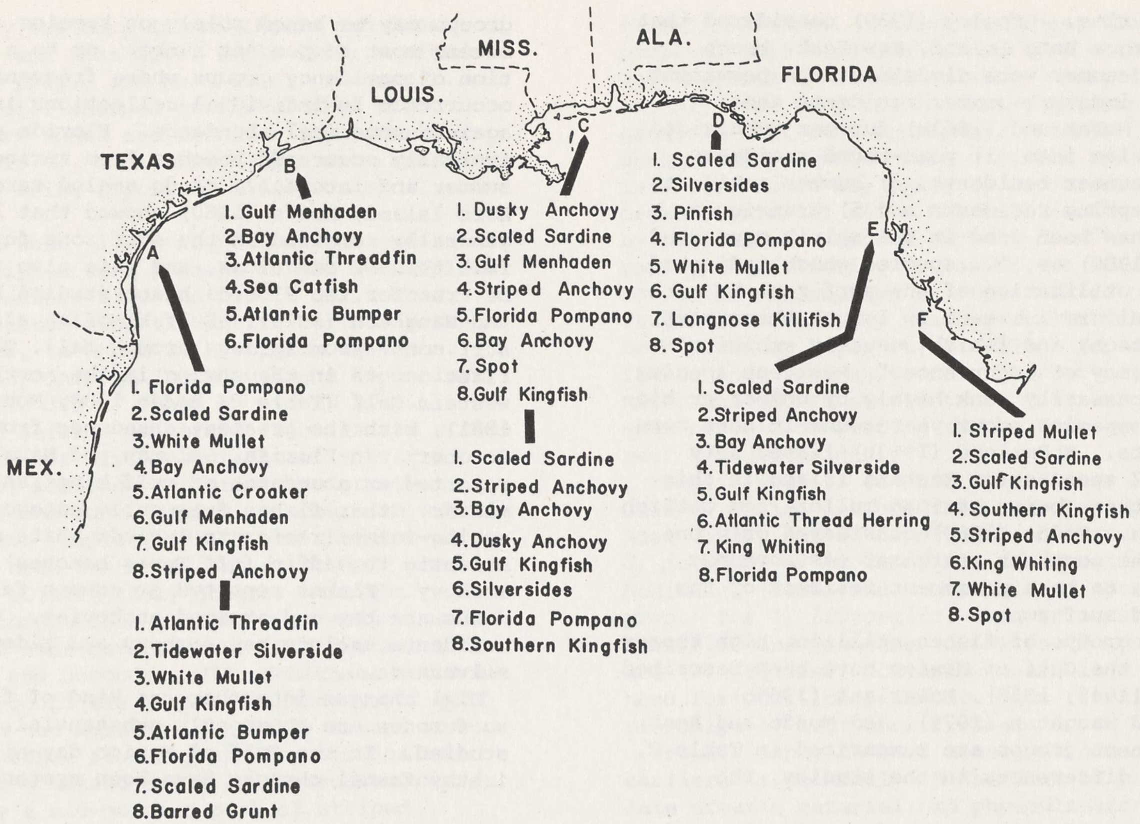


Fig. 2. A listing of the 6-8 most abundant fishes from surf zone environments in the Gulf of Mexico. A = Mustang Island, B = Gilchrist, Texas, C = Horn Island, D = Panama City, E = Pinellas Co., F = Sanibel Island. Sources for each area are given in Table 1 except that data from Gunter 1945 and Reid 1956 are not shown. Earlier studies are listed above later studies from the same area.

difficulty of sampling the various regions of the surf zone.

Temporal Dynamics

Fish assemblages utilizing surf zone habitats show strong temporal structuring on a seasonal and diel basis and also from the timing in the life history of a species when the habitat is occupied. Such dynamism makes it difficult to compare studies due to possible seasonal or diel differences in collecting effort, or gear susceptibility of different life history stages.

Seasonal changes in surf zone ichthyofaunas have been documented for all areas listed in Fig. 2. The seasonal pattern demonstrates both qualitative and quantitative effects. The general pattern is for fish abundance to be lowest off Gulf beaches in the winter, rising to peak abundances in the summer or fall. McFarland (1963b), Modde and Ross (1981), Naughton and Saloman (1978) and Saloman and Naughton (1979) all found the greatest concentration of fishes during late summer to fall. During 1978-79 density of fishes was highest during the summer (June - August) on Horn Island ($\bar{x}$= 2.8 m^{-2}) and this value significantly exceeded spring and fall levels (Kruskall-Wallis Test, $P < .05$) of .8 and .5 m^{-2}, respectively (Ross et al. in prep.). The density of fishes reported by McFarland (1963b) from Mustang Island was approximately an order of magnitude lower, being .3 m^{-2} in the spring-summer and .02 m^{-2} in the winter. Much of the difference may be due to the larger mesh size used by McFarland which would have allowed the numerous smaller fishes to escape.

The standing crop for Horn Island was also significantly greater in the summer with an average of 5.2 g m^{-2} (Ross et al. in prep.). In comparison, Naughton and Saloman (1978) recorded an annual standing crop of .75 g m^{-2} for Panama City Beach with a June - August average of 2 g m^{-2}. The spring-summer standing crop reported by McFarland (1963b) for Mustang Island was 11.7 g m^{-2}, exceeding the Horn Island value. The ranges, however, overlap.

In contrast to the seasonal pattern of the Gulf of Mexico studies, Anderson et al. (1977) reported that the greatest number and weight of fishes was taken from a North Carolina surf zone in the winter, although more species were collected during the summer. In part, they attributed the winter rise in catch to decreased net avoidance of larger fishes caused by lower water temperatures.

Surf zone habitats may be briefly encountered by fishes moving along the coasts through passes into more protected waters, or by species that remain in the outer beach system for longer periods of time. Greeley (1939) considered that fishes using a Long Island, New York, beach during the summer were divisible into permanent residents, immature summer residents and migrants. McFarland (1963b) further subdivided use categories into: 1) year-round residents, 2) spring-summer residents, 3) summer residents, 4) winter-spring residents and 5) transients. Residency has been used in the spirit expressed by Modde (1980) as, "...species which indicated adolescent utilization of the surf zone by a relatively uniform increase in length throughout a given season, and [which] usually exhibited a high frequency of occurrence." Resident species may not necessarily rank highly by number or biomass. Few species occur year-round in surf zone environments. McFarland (1963b) listed only three of 47 species for Mustang Island in this category, these being striped mullet, sea catfish and pinfish. Modde (1980) considered only one species, the southern stargazer *(Astroscopus y-graecum)*, to be a permanent resident of the Horn Island surf zone.

Seasonal groups of fishes utilizing high energy beaches in the Gulf of Mexico have been described by Gunter (1945; 1958), McFarland (1963b), Saloman and Naughton (1979), and Modde and Ross (1981). These groups are summarized in Table 2, but due to differences in the studies, the groups may be based solely on species contributing most to percent number, or to a consideration of residency groups where frequency of occurrence in individual collections is balanced against numerical abundance. Florida pompano typically occur off beaches from spring through summer and into fall, as do scaled sardines. On Horn Island, Modde (1980) showed that *H. jaguana* generally remained in the surf zone further into fall than *T. carolinus*, and this also appears to be true for the Florida beach studied by Saloman and Naughton (1979). Gulf kingfish also occupy surf zones from spring through fall. This species first occurs in the spring in the northern and western Gulf (Table 2; Modde 1980; McMichael 1981), with the greatest abundance from June to October. In Florida, Saloman and Naughton (1979) reported an abundance of gulf kingfish into the winter. Other fishes frequently categorized as spring-summer residents include white mullet, Atlantic threadfin (off Texas beaches), and bay anchovy. Fishes reported as common fall residents are bay and striped anchovies. Winter residents include bay anchovy and tidewater silverside.

Diel changes in number and kind of fishes in surf zones are apparently substantial, but less studied. In the Gulf of Mexico day-night ichthyofaunal changes have been systematically

Table 2. Seasonal components of surf zone fish faunas in the Gulf of Mexico. Rankings are based on numerical abundance unless indicated.

LOCATION	SPRING	SUMMER	FALL	WINTER	SOURCE
Mustang Is.	bay anchovy white mullet Atlantic threadfin	Atlantic threadfin scaled sardine Florida pompano	bay anchovy scaled sardine Florida pompano	white mullet bay anchovy	Gunter 1945
Mustang Is.	Florida pompano white mullet Atlantic croaker	Florida pompano scaled sardine menhaden	scaled sardine Florida pompano bay anchovy	tidewater silverside longnose killifish	Gunter 1958
Mustang Is.[1]	Atlantic threadfin tidewater silverside gulf kingfish Florida pompano scaled sardine	crevalle jack Atlantic bumper Atlantic croaker Spanish mackerel harvest fish		silver perch	McFarland 1963b
Horn Island[2]	dusky anchovy scaled sardine mojarras *(Eucinostomus* sp.) Florida pompano	flat anchovy Spanish sardine white mullet striped mullet gulf kingfish	striped anchovy gulf kingfish	gulf menhaden pinfish spot striped mullet	Modde and Ross 1981
Pinellas Co.	striped anchovy bay anchovy tidewater silverside scaled sardine king whiting	scaled sardine gulf kingfish king whiting Florida pompano tidewater silverside	scaled sardine Atlantic thread-herring tidewater silverside striped anchovy gulf kingfish	bay anchovy gulf kingfish scaled sardine tidewater silverside striped anchovy	Saloman and Naughton 1979

[1] Seasonal categories are: spring-summer, summer, winter-spring; inclusion is based on residency.

[2] Inclusion is based on frequency of occurrence.

studied only for Horn Island (Modde and Ross) 1981; Modde and Ross 1983; Ruple 1983; McMichael and Ross in prep.; and Ross et al. in prep.). Studies of diel changes of fishes from U. S. Atlantic surf zones are also few (e.g. Merriman 1947; Daly 1970), even though such data are recognized as being important (Anderson et al. 1977).

Modde and Ross (1981) found that the greatest number of fishes were present in the Horn Island surf zone between 0300 and 0900 h CST. This pattern occurred over the entire period, March to September, in which 24 h seining was done. A later study on Horn Island using a 50 m block net enclosing 300 m^2 (Ross et al. in prep.) showed less defined patterns. Biomass and standing crop did not differ significantly over a 24 h period, although variation was greatest around dawn and dusk. Larval fishes also exhibit diel changes. Ruple (1983) found that larval density in both the inner and outer surf zone region was significantly greater at night.

Species composition changes over a 24 h period in the surf zone environment. For instance, in June, July and October, 1979, McMichael and Ross (in prep.) found the greatest abundance of gulf kingfish in the morning, generally around sunrise. Abundance of dusky anchovy and scaled sardine was greatest early in the morning, followed by a mid-morning peak of striped anchovy (Modde and Ross 1981). Pompano were generally more abundant later in the day, but did not show well developed diel abundance patterns.

Time of day is undoubtedly not the only factor important in influencing diel changes in number and standing crop of fishes in surf zones. Tide level is also of likely importance as Modde and Ross (1981) found that tide was the most important environmental factor influencing clupeoid abundance on a seasonal basis. However, the analysis did not include time as a variable and was limited to fishes collected during the day. The available information suggests that clupeoid fishes may be more variable on a 24 h basis than percoids such as gulf kingfish or pompano.

Uses of the Surf Zone Habitat by Fishes

The surf zone region may be used by various life history stages of fishes as a shelter from predation by larger fishes, or as a feeding, or spawning area. Use as a nursery area (a shelter and feeding site for young fishes) is included in these categories. As a group, fishes in the various resident categories likely use surf areas for most or all of these functions, although few studies have addressed this problem.

The summer resident fishes of the Horn Island surf zone are divisible into two groups: 1) those using the surf zone as a feeding area and perhaps also as a shelter area; and 2) those using the area primarily as a shelter area (Modde and Ross 1983). The logic in assigning fishes to these two groups was the relationship between daily time of greatest feeding activity in the surf zone and time of greatest abundance. The approach assumes that feeding periodicity of fishes captured nearshore reflects their activity further offshore. Scaled sardines, Florida pompano, gulf kingfish and striped anchovy all use the area as a feeding site, while dusky anchovy feed very little during their period of greatest surf zone abundance. Fishes, such as dusky anchovy, which feed offshore and then move into surf zones may serve as importers of organic material which may be directly utilized by particulate feeders such as *Emerita* or trapped by the filtering action of the swash zone for later consumption by other macro- or meiofaunal elements. An analogous role has recently been shown by Meyer et al. (1983) for coral reef fishes that feed away from the reef site at night and import nutrients to the reef proper when schools of resting fishes form over the reef during the day.

Trophic studies of surf zone fishes in the Gulf of Mexico include the work of Modde and Ross (1983) for *T. carolinus, M. littoralis, H. jaguana, A. lyolepis* and *A. hepsetus;* McMichael (1981) and McMichael and Ross (in prep.) for *M. littoralis, M. americanus* and *M. saxatilis* and Finucane (1969) for *T. carolinus* and *T. falcatus*. Clearly, there is a great need for additional inquiry into trophic relationships of surf zone fishes.

Trophic input to surf zones, as discussed earlier, is primarily in the form of particulate organic material and phytoplankton. McFarland (1963b) pointed out that planktivorous fishes dominated the surf zone of Mustang Island, and on Horn Island the numerically dominant fishes are again primarily planktivores. Only gulf kingfish and larger Florida pompano (of the five species studied by Modde and Ross 1983) utilized benthic prey. The importance of plankton to the surf zone ecosystem is illustrated by the partial food web for the summer, subtidal beach area of Horn Island (Fig. 3). Since studies of invertebrate zonation and feeding relationships are not available for this area, data are used from other regions. More detailed food webs for other surf zone areas are given in Hedgpeth (1957) and McLachlan et al. (1981a). Various species of *Donax* (Dahl 1952; Brown 1964 and Leber 1982) and *Emerita* (Dahl 1952; Leber 1982) are known to be particulate feeders utilizing organic deposits and phytoplankton. Macroinvertebrates other than *Donax* and *Emerita* are listed together in Fig. 3. Data on food habits of various macrofaunal invertebrates from surf zones, including polychaetes, cumaceans, amphipods (especially Haustoriidae) and isopods, are given in Brown (1964), Dahl (1952), and Dexter (1969). These organisms include direct and indirect deposit feeders and phytoplanktivores.

Assigning fishes to trophic groups is difficult since there are often ontogenetic trophic progressions (e.g. Ross 1978; Livingston 1982). While such progressions occur for Horn Island fishes, the broad trophic categories result in minimal distortion. Size groups which show changes are listed separately. In particular, larger bay anchovies consume fishes as well as zooplankton; larger scaled sardines become more herbivorous; and larger pompano and gulf kingfish prey increasingly on fishes. Feeding data on

A. mitchilli are from Darnell (1958) and Carr and Adams (1973), and data for *Menidia beryllina* are also from Carr and Adams. Food habits of *M. cephalus* are described by Darnell (1958), Odum (1970) and DeSilva and Wijeyaratne (1977). Less information is available for *M. curema*, although it is also considered to consume benthic microplant material and macroplant detritus (Odum 1970).

While the majority of trophic units utilize water column prey, the abundant benthic macroinvertebrates, *Donax* and *Emerita*, are also important food items to certain fishes, especially gulf kingfish and Florida pompano. It is particularly intriguing to note the consumption of *Donax* siphon tips, primarily by small kingfish and pompano. Browsing (sensu Choat 1982) of infaunal invertebrates has recently been examined by Woodin (1982) and Peterson and Quammen (1982). The latter authors found that siphon nipping substantially reduced growth rates of the bivalve *Protothaca staminae* in sandy habitats, but had little effect on clam mortality. Browsing by surf zone fishes on *Donax* siphon tips may represent an important energy pathway from particulate organic matter and primary production into higher consumer levels. Larger kingfish and pompano abandon browsing and consume entire *Donax*.

Surf zones are important nursery areas for certain fish species. Post-larval and juvenile fishes comprise the most numerous element of the surf zone ichthyofauna (Modde 1980; Modde and Ross 1981), and late larval and juvenile stages of some species may remain in the surf zone for a considerable period of time (cf. Table 2). Species which appear to be highly dependent on surf zones as nursery areas are: Florida pompano (Modde 1980; Finucane 1969), gulf kingfish (Modde 1980; McMichael and Ross in prep.), scaled sardines (Modde 1980) and striped anchovy (Ruple 1983). While dusky anchovy are often abundant in surf zones, Modde (1980) found that there was no increase in size structure over time, indicating a continual influx and departure of juvenile fish. Both white and striped mullet also appear to use surf zone regions as nursery areas (Anderson et al. 1977), as do gulf menhaden and spot (Ruple 1983) and the two additional species of *Menticirrhus*, *M. saxatilis* and *M. americanus* (Greeley 1939; Irwin 1970; McMichael and Ross in prep.). In addition, species of generally lower abundance such as *Astroscopus y-graecum* are closely associated with surf zone areas. Recently, Lenanton (1982) pointed out the importance of alternative, nonestuarine, nursery areas for Australian coastal fishes. He found that a number of species considered to be estuarine dependent were not exclusively so. The important point is that, while estuaries are extremely important nursery areas, many other coastal habitats are used as well. The importance of the surf zone habitat to species using it for a short time is difficult to discern. If many species move along the outer, exposed beaches feeding on abundant zooplankton before entering estuaries, then the quality of the surf zone habitat may have a much further reaching effect on population success of commerical, sport and non-game fishes than we can understand by looking at lists of species which remain in the area and are highly abundant.

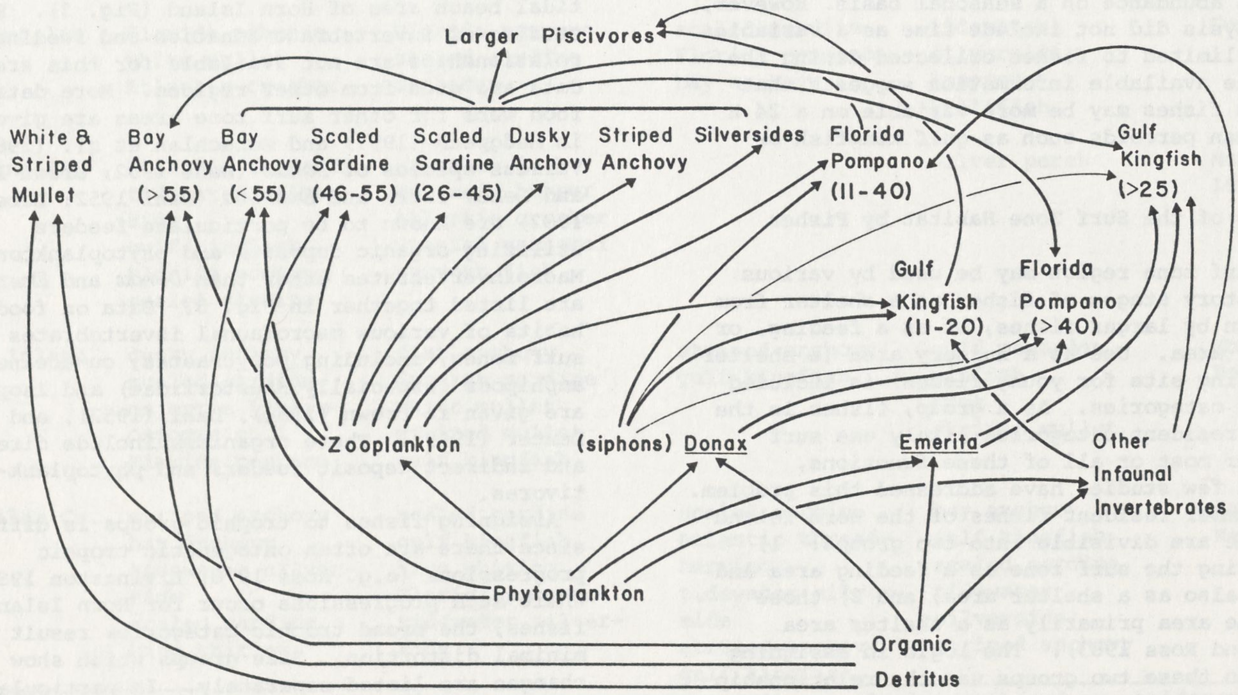


Fig. 3. A partial summer food web for the sub-tidal exposed beach of Horn Island, Mississippi. Numbers refer to sizes in mm standard length.

ACKNOWLEDGMENTS

I am grateful to Stephen V. Cofer-Shabica for his support and interest in studies of coastal environments and for providing the challenge to prepare this review paper. I thank Robert S. Prezant and Yvonne Ross for helpful comments on this manuscript.

LITERATURE CITED

Anderson, W.D., Jr., J.K. Dias, R.K. Dias, D.M. Cupka and N.A. Chamberlain. 1977. U.S. Dep. Commer., NOAA Tech. Rep., NMFS SSRF-704, 23 p.

Ansell, A.D., P. Sivadas, B. Narayanan, V.N. Sankaranarayanan, and A. Trevallion. 1972. The ecology of two sandy beaches in southwest India. I. Seasonal changes in physical and chemical factors, and in the macrofauna. Mar. Biol. (Berl.) 17:38-62.

Bagur, J.D. 1978. Barrier islands of the Atlantic and Gulf Coasts of the United States: An annotated bibliography. U.S. Fish and Wildlife Service Biological Services Program FWS/OBS-77/56. 215 p.

Brown, A.C. 1964. Food relationships on the intertidal sandy beaches of the Cape Peninsula. S. Afr. J. Sci. 60:35-41.

Carr, W.E.S. and C.A. Adams. 1973. Food habits of juvenile marine fishes occupying seagrass beds in the estuarine zone near Crystal River, Florida. Trans. Amer. Fish. Soc. 102: 511-540.

Choat, J.H. 1982. Fish feeding and the structure of benthic communities in temperate waters. Ann. Rev. Ecol. Syst. 13: 423-429.

Dahl, E. 1952. Ecology and zonation of fauna of sand beaches. Oikos 4:1-27.

Daly, R.J. 1970. Systematics of southern Florida anchovies (Pisces: Engraulidae). Bull. Mar. Sci. 20:70-104.

Darnell, R.M. 1958. Food habits of fishes and larger invertebrates of Lake Pontchartrain, Louisiana, an estuarine community. Publ. Inst. Mar. Sci. Univ. Tex. 5:353-416.

Dexter, D.M. 1969. Structure of an intertidal sandy beach community in North Carolina. Chesapeake. Sci. 10:93-98.

DeSilva, S.S. And M.J.S. Wijeyaratne. 1977. Studies on the biology of young grey mullet, *Mugil cephalus* L. II. Food and feeding. Aquaculture. 12:157-167.

Diaz, H. 1980. The mole crab *Emerita talpoida* (Say): A case of changing life history patterns. Ecol. Monogr. 50:437-456.

Dye, A.H. 1981. A study of benthic oxygen consumption of exposed sandy beaches. Estuarine Coastal Shelf Sci. 13:671-680.

Dye, A.H., A. McLachlan and T. Wooldridge. 1981. The ecology of sandy beaches in Natal. S. Afr. J. Zool. 16:200-209.

Efford, I.E. 1966. Feeding in the sand crab. *Emerita* analoga (Decapoda:Hippidae). Crustaceana 10:167-182.

Finucane, J.H. 1969. Ecology of the pompano *(Trachinotus carolinus)* and the permit *(T. falcatus)* in Florida. Trans. Am. Fish. Soc. 98:478-486.

Greeley, J.R. 1939. Fishes and habitat conditions of the shore zone based upon July and August seining investigations, p. 72-92. In: A biological survey of the salt waters of Long Island 1938, Part II. State of New York Conservation Dept., Albany.

Gunter, G. 1945. Studies on marine fishes of Texas. Publ. Inst. Mar. Sci., Univ. Tex. 1:1-190.

Gunter, G. 1958. Population studies of the shallow water fishes of an outer beach in south Texas. Pub. Inst. Mar. Sci., Univ. Tex. 5:186-193.

Gunter, G. 1979. Notes on sea beach ecology. Food sources on sandy beaches and localized diatom blooms bordering Gulf beaches. Gulf Res. Rep. 6:305-307.

Gunter, G. and G.E. Hall. 1965. A biological investigation of the Caloosahatchee Estuary of Florida. Gulf Res. Rep. 2:1-71.

Hedgpeth, J.R. (ed.) 1957. Treatise on marine ecology and paleoecology. Vol 1. Ecology. Geol. Soc. Amer., Mem. No. 67. 1296 p.

Hill, G.W. and R.E. Hunter. 1976. Interaction of biological and geological processes in the beach and nearshore environments, northern Padre Island, Texas. Soc. Econ. Paleo. Miner., Special Publ. No. 24:169-187.

Ingle, J.C., Jr. 1966. The movement of beach sand. Elsevier, New York. 221 p.

Irwin, R.J. 1970. Georgraphical variations, systematics, and general biology of shore fishes of the genus *Menticirrhus*, family Sciaenidae. Ph.D. Diss., Tulane Univ., 291 p.

Leber, K.M. 1982. Seasonality of macroinvertebrates on a temperate, high wave energy sandy beach. Bull. Mar. Sci. 32:86-98.

Lenanton, R.C.J. 1982. Alternative non-estuarine nursery habitats for some commerically and recreationally important fish species of Southwestern Australia. Aust. J. Mar. Freshw. Res. 33:881-900.

Lenanton, R.C.J., A.I. Robertson and J.A. Hansen. 1982. Nearshore accumulations of detached macrophytes as nursery areas for fish. Mar. Ecol. Prog. Ser. 9:51-57.

Livingston, R.J. 1982 Trophic organization of fishes in a coastal seagrass system. Mar. Ecol. Prog. Ser. 7:1-12.

McFarland, W.N. 1963a. Seasonal plankton productivity in the surfzone of a south Texas beach. Pub. Inst. Mar. Sci. Univ. Texas 9:77-90.

McFarland, W.N. 1963b. Seasonal change in the number and the biomass of fishes from the surf at Mustang Island, Texas. Pub. Inst. Mar. Sci. Univ. Texas 9:91-105.

McLachlan, A. 1979. Volumes of seawater filtered by East Cape sandy beaches. S. Afr. J. Sci. 75: 75-79.

McLachlan, A. 1980a. Exposed sandy beaches as semi-enclosed ecosystems. Mar. Environ. Res. 4:59-63.

McLachlan. A. 1980b. The definition of sandy beaches in relation to exposure: a simple rating system. S. Afr. J. Sci. 76:137-138.

McLachlan, A. 1982. A model for the estimation of water filtration and nutrient generation by exposed sandy beaches. Mar. Environ. Res. 6:37-47.

McLachlan, A., T. Erasmus, A.H. Dye, T. Wooldridge, G. vander Horst, G. Rossouw, T.A. Lasiak, and L. McGwynne. 1981a. Sand beach energetics: An ecosystem approach towards a high energy interface. Estuarine Coastal Shelf Sci. 13:11-25.

McLachlan, A., T. Wooldridge and A.H. Dye. 1981b. The ecology of sandy beaches in southern Africa. S. Afr. J. Zool. 16:219-231.

McMichael, R.H., Jr. 1981. Utilization of the surf zone of a northern Gulf Coast barrier island by the *Menticirrhus* complex (Pisces: Sciaenidae). Masters Thesis, Univ. Southern Miss., Hattiesburg. 86 p.

Merriman, D. 1947. Notes on the midsummer ichthyofauna of a Connecticut beach at different tide levels. Copeia 1947: 281-286.

Meyer, J.L., E.T. Schultz and G.S. Helfman. 1983. Fish schools: an asset to corals. Science 220:1047-1049.

Meyer-Reil, L.A., R. Dawson, G. Liebezeit and H. Tiedge. 1978. Fluctuations and interactions of bacterial activity in sandy beach sediments and overlying waters. Mar. Biol. (Berl.) 48: 161-171.

Modde, T. 1980. Growth and residency of juvenile fishes within a surf zone habitat in the Gulf of Mexico. Gulf Res. Rep. 6:377-385.

Modde, T. and S.T. Ross. 1981. Seasonality of fishes occupying a surf zone habitat in the northern Gulf of Mexico. U.S. Nat. Mar. Fish. Serv. Fish. Bull. 78:911-922.

Modde, T. and S.T. Ross. 1983. Trophic relationships of fishes occurring within a surf zone habitat in the northern Gulf of Mexico. Northeast Gulf Sci. 6:31-42.

Naughton, S.P. and C.H. Saloman. 1978. Fishes of the nearshore zone of St. Andrew Bay, Florida, and adjacent coast. Northeast Gulf Sci. 2:43-55.

Nummedal, D. 1982. Barrier islands. Tech. Rept. No. 82-3. Coastal Research Group, Dept. Geology. Louis. St. Univ., Baton Rouge.

Odum, W.E. 1970. Utilization of the direct grazing and plant detritus food chains by the striped mullet *Mugil cephalus*, p. 222-240. In: J. Steele (ed.) Marine food chains. Oliver and Boyd, Edinburgh. 552 p.

Pearse, A.S., H.J. Humm, and G.W. Wharton. 1942. Ecology of sand beaches at Beaufort, North Carolina. Ecol. Monogr. 12:135-140.

Peterson, C.H. and M.L. Quammen. 1982. Siphon nipping: its importance to small fishes and its impact on growth of the bivalve *Protothaca staminea* (Conrad). J. Exp. Mar. Biol. Ecol. 63:249-268.

Reid. G.K., Jr. 1955a. A summer study of the biology and ecology of East Bay, Texas. Part I. Introduction, description of area, methods, some aspects of the fish community, the invertebrate fauna. Tex. J. Sci. 7:316-343.

Reid, G.K., Jr. 1955b. A summer study of the biology and ecology of East Bay, Texas. Part II. the fish fauna of East Bay, the Gulf beach, and summary. Tex. J. Sci. 7:430-453.

Reid, G.K., Jr. 1956. Observations on the eulittoral ichthyofauna of the Texas Gulf Coast. Southwest. Nat. 1:157-165.

Riedl, R. 1971. How much seawater passes through sandy beaches? Int. Rev. Gesamten Hydrobiol. 56:923-946.

Riedl, R. and E.A. McMahan. 1974. High energy beaches, p. 180-251. In: H.T. Odum, B.J. Copeland and E.A. McMahan (eds.). Coastal Ecological Systems of the United States. Conservation Found., Wash. D.C.

Ross, S.T. 1978. Trophic ontogeny of the leopard searobin, *Prionotus scitulus* (Pisces: Triglidae) U.S. Nat. Mar. Fish. Serv. Fish. Bull. 76: 225-234.

Ruple, D.L. 1983. Occurrence of larval fishes in the surf zone of a northern Gulf of Mexico barrier island. Estuarine, Coastal, Shelf Sci. In Press.

Saloman, C.H. and S.P. Naughton, 1978. Benthic invertebrates inhabiting the swash zone of Panama City Beach, Florida. Northeast Gulf Sci. 2:65-72.

Saloman, C.H. and S.P. Naughton. 1979. Fishes of the littoral zone, Pinellas County, Florida. Fla. Sci. 42:85-93.

Schaefer, R.H. 1967. Species composition, size and seasonal abundance of fish in the surf waters of Long Island. N.Y. Fish Game J. 14:1-46.

Schiffman, A. 1965. Energy measurements in the swash-surf zone. Limnol. Oceanogr. 10:255-260.

Shelton, C.R. and P.B. Robertson. 1981. Community structure of intertidal macrofauna on two surf-exposed Texas sandy beaches. Bull. Mar. Sci. 31:833-842.

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw Hill, New York.

Springer, V.G. and K.D. Woodburn. 1960. An ecological study of the fishes of the Tampa Bay area. Fl. Board Conserv., Mar. Lab., Prof. Pap. Ser. 1, 104 p.

Taylor, J.L., D.L. Feigenbaum and M.L. Stursa. 1973. Utilization of marine and coastal resources, p. IV-1-IV-63. In: J.I. Jones, R,E, Ring, M.O. Rinkel, and R.E. Smith (eds.). A summary of knowledge of the eastern Gulf of Mexico. State Univ. Syst. Fla. Inst. Oceanogr., St. Peterburg, FL.

Wade, B.A. 1967. Studies on the biology of the West Indian beach clam, *Donax denticulatus*. 1. Ecology. Bull. Mar. Sci. 17:149-174.

Woodin, S.A. 1982. Browsing: important in marine sedimentary environments? Spionid polychaete examples. J. Exp. Mar. Biol. Ecol. 60:35-45.

[illegible] A., [illegible] Erasmus, A.H. Dye, T. Wooldridge, G. Van der Horst, G. Rossouw, T.A. Lasiak, and L. McGwynne. 1981. Sand beach energetics: an ecosystem approach towards a high energy interface. Estuarine Coast. Shelf Sci. 13:11-25.

[illegible] T. Wooldridge and A.H. Dye. 1981b. [illegible] of sandy beaches in southern Africa. S. Afr. J. Zool. 16:219-231.

[illegible] R.F., Jr. 1982. Utilization of the surf zone of three Gulf Coast barrier islands by the [illegible] Univ. Southern Miss., [illegible] 98 p.

[illegible] 1977. [illegible] on the [illegible] of [illegible] beach at different tide levels. [illegible] 1977: 281-288.

[illegible], R.W. [illegible] and D.J. [illegible]. 1976. [illegible] schools: an essay on [illegible] 104-1085.

[illegible], N. [illegible] and [illegible] 1978. Fluctuations and interactions of [illegible] sediments and [illegible] 161-1.

[illegible] 1980. Growth and residency of juvenile fishes within a surf zone habitat in the Gulf of Mexico. Gulf Res. Rep. 6:377-385.

[illegible] and [illegible] 1983. [illegible] fishes occurring [illegible] zone habitat in the northern Gulf of Mexico. U.S. Natl. Mar. Fish. Serv. Fish. Bull. 78:911-9[illegible]

[illegible] 1983. [illegible] of [illegible] within a [illegible] habitat in the northern Gulf of Mexico. Northeast Gulf Sci. 6:[illegible]

[illegible] and [illegible] 1978. Fishes [illegible] of [illegible] Bay, Florida, and adjacent waters. Northeast Gulf Sci. 2:43-5[illegible]

[illegible] 1982. [illegible] Coastal [illegible] Group, Dept. Geology, [illegible] Sc. [illegible] Series [illegible]

[illegible] 1970. Trophic [illegible] of the [illegible] and [illegible] detritus food chains [illegible] [illegible] J. [illegible] Marine food chains. [illegible] 552 p.

[illegible] and G.W. [illegible] 1962. Ecology of sand beaches [illegible] North Carolina. Ecol. Monogr. 32:[illegible]

Peterson, C.H. and [illegible] 1984. [illegible] its importance to small [illegible] and the [illegible] of the [illegible] Exp. Mar. Biol. Ecol. [illegible]-265.

Reid, G.K., Jr. 1955a. A summer study of the biology and ecology of East Bay, Texas. Part I. Introduction, description of area, methods, some aspects of the fish community, the invertebrate fauna. Tex. J. Sci. 7:316-343.

Reid, G.K., Jr. 1955b. A summer study of the biology and ecology of East Bay, Texas. Part II. The fish fauna of East Bay, the Gulf beach, and summary. Tex. J. Sci. 7:430-453.

[illegible], Jr. 1955. [illegible] on the [illegible] of the Texas Gulf Coast. [illegible] Nat. [illegible]:131-133.

[illegible] 1971. [illegible] through [illegible] Hydrol. [illegible]

[illegible] and [illegible] 1974. [illegible] Res. [illegible] In: H.T. [illegible] Coastal Ecological Systems of the [illegible] Conservation Found. [illegible]

Ross, S.T. 1978. [illegible] of the leopard searobin, [illegible] (Pisces: Triglidae). U.S. Nat. Mar. Fish. Serv. Fish. Bull. 76: 225-234.

[illegible] 1983. Occurrence of larval fishes in the surf zone of a northern Gulf of Mexico barrier island. [illegible] Coastal Shelf Sci. In press.

Saloman, C.H. and S.P. Naughton. 1978. Benthic macroinvertebrates inhabiting the swash zone of Panama City Beach, Florida. Northeast Gulf Sci. 2:6[illegible]

Saloman, C.H. and [illegible] 1970. [illegible] the intertidal zone, Pinellas County, Florida. Fla. Sci. 47:83-[illegible]

[illegible] R.M. 1967. Species composition, size and seasonal abundance of fish in the surf waters of Long Island. N.Y. Fish Game J. [illegible]

[illegible] 1968. [illegible] in the [illegible] zone. Limnol. Oceanogr. [illegible] 759-608.

[illegible] and [illegible] 1981. Community structure of intertidal macrofauna on two surf-exposed [illegible] sandy beaches. Bull. Mar. Sci. 31:[illegible]

Siegel, S. [illegible] Nonparametric statistics for the behavioral sciences. McGraw-Hill, New York.

[illegible] and E.B. [illegible] 1940. [illegible] study of the fishes of the [illegible] Bay [illegible] Inst. [illegible] Lab. Publ. [illegible]

Taylor, [illegible] and W.L. [illegible] 1975. [illegible] of [illegible] and coastal [illegible] In: [illegible] J.L. [illegible] King, W.E. [illegible] and R.L. [illegible] (eds.). A summary of knowledge of the eastern Gulf of Mexico. State Univ. Syst. Fla. Inst. Oceanogr. [illegible]

[illegible] 1967. Studies on the biology of [illegible] sand beach [illegible]. [illegible] Ecology. [illegible] Mar. [illegible] 158-174.

Whitlatch, R.B. 1977. [illegible] important in marine sedimentary environments: [illegible] Biol. Ecol. 60:[illegible]

Wild Salmonid Watch, 5,1-4.

WILD SALMONID WATCH

A Wild Salmon, Trout and Charr Watch:

An International Strategy for Salmonid Conservation

Newsletter No 5

This is the fifth in a series of biannual Newsletters covering the activities of the Wild Salmonid Watch. This issue includes a list of (new) members, a note on membership, reports from Scotland, Canada and Sweden, and details of two publications.

January 1984

MEMBERS AND THEIR INTERESTS (3RD ADDENDUM)

CANADA A.T. BIELAK, Department of Biology, University of Waterloo, Waterloo, Ontario N2L 3G1. *Life history strategies of Quebec Atlantic salmon.*

SWITZERLAND CHRISTIAN RIPPMAN, Federal Institute of Water Resources, EAWG, CH-6047 Kastanierbaun, Luzern. *Salmonids in Switzerland.*

U.S.A. SCOTT LINDELL (change of address), Cooperative Fishery Research Unit, U.S. Fish & Wildlife Service, Holdsworth Hall, University of Massachusetts, Amherst, Massachusetts 01003. *Genetic implications of the restoration of salmon to the Connecticut River.* EUGENE UDK PERRIN, Children's Hospital of Michigan, 3901 Beaubian Boulevard, Detroit, Michigan 48201. *Salmonids and the environment.*

U.S.S.R. S.M. KONOVALOV (change of address), Institute of Ecology, Academy of Science, Tolljati 3, Kujbyshev Region. *Salmonid conservation and management problems.*

MEMBERSHIP

The above additions bring the present membership to a healthy 98 watchers from 18 countries. There is also a significant number of people who wish to be kept informed about the activities of the WSW, even although they themselves are not active watchers. However, in addition to both these groups it seems likely that there may be people who are not yet aware of the WSW or its objectives. Members are encouraged to contact anyone who might be interested and give them details. Alternatively the Secretary will be pleased to send out the current Newsletter to any names and addresses received.

SCOTLAND

Loch Insh in the Spey Valley of Scotland has a charr population which is distinctive for its large size (the previous British rod-caught record came from here) and the fact that it spawns in running water. Most Scottish charr spawn in lakes. One of the feeder streams to Loch Insh, which has long been recognised as an important spawning ground for the charr, is the Dunachton Burn. Recently, where the Dunachton Burn flows under the new A9 Perth-Inverness road, it was put into a culvert, the length and gradient of which are such that the charr, together with salmon and sea trout, were unable to reach their spawning grounds in 1981 or 1982.

The problem was brought to the attention of the Scottish Office but when no official action had been taken by October 1983, local volunteers from the Scottish Wildlife Trust built a temporary fish ladder. The attendant publicity may have been more successful since the Scottish Office are now apparently considering making changes to the culvert to allow fish to swim through.

CANADA

Makivik Corporation Research Department recently released a report 'Life History and Present Status of Anadromous Arctic Char (Salvelinus alpinus L.) in Northern Quebec with case studies on the George, Payne and Kovik Rivers' by David J. Gillis, Marc Allard and William B. Kemp.

The report includes sections on natural history, the traditional harvest and present utilization of Arctic Charr as well as the case studies. The study was undertaken because the Inuit of Northern Quebec were concerned that charr stocks could not survive the changes in patterns of subsistence harvesting commercial fishing and sports fishing that were occurring.

As a result of introductions made at the First International Symposium on Arctic Charr in Winnipeg in 1981 blood samples from about 500 Arctic Charr from N. Quebec were sent to Dr Rolf Gydemo, Institute of Freshwater Research, Drottningholm, Sweden for analysis. Preliminary results suggest two distinct populations in each of the Kovik and George River fisheries which helps emphasize the complexity of modern fisheries assessment.

It is interesting that the Inuit of Northern Quebec with their fledgling research organization were one of the first groups to officially support and benefit from the concept of the Wild Salmonid Watch (or Wild Trout and Char Watch as it was tentatively called in 1980). The charr study report is available at nominal cost from: Kativik Regional Government, P O Box 09, Kinjjuak, Quebec, JOM ICO, Canada.

SWEDEN

Johan Hammar reports that the chemical analyses of sea water and air in the Arctic during the Swedish Ymer-80 expedition showed extremely low levels of pollutants. On the other hand the birds in the same area show very high levels of pesticides. Where do these pesticides come from? Are they air driven? If so landlocked populations of Arctic charr should be affected. In order to find out, samples of Arctic charr from various habitats are being analysed for pesticides and metals.

The problems of mercury in fish are routinely monitored by the National Environment Protection Board, which uses pike as an indicator organism. High levels occur even in northern Sweden. In these areas people usually do not eat pike but mainly charr, trout and whitefish. The mercury situation in these fish is unknown. Samples of Arctic charr from a lowland lake indicated high levels. Now about 15 specimens per month from October 1982 to September 1983 from Lake Storsjouten, north Sweden are being analysed for as many metals as possible. The study is a joint project between the Institute of Freshwater Research and the National Swedish Environmental Protection Board. Thereafter it is hoped to use Arctic charr, the most widely distributed salmonid in the northern hemisphere, as an indicator of the distribution of different heavy metals and possibly also pesticides.

WILD SALMON & TROUT CONFERENCE

This publication records the presented papers and transcribed discussions of the Wild Salmon and Trout Conference held on March 1983, in Seattle, Washington. It includes information on wild stocks of salmon, steelhead and trout in the Pacific Northwest. The topics range from assessment of the current status of wild salmonids to descriptions of public involvement in making and implementing policies for managing these fish resources. Most of the presentations were given by fisheries scientists and managers. Their focus is on the wild stocks of salmon, steelhead and trout in the Pacific Northwest and what is happening to these stocks given the consequences of fishing pressure, management practices, habitat alterations and hatchery production. The solutions offered during the symposium for recovering declining trends in wild salmonid fisheries included: 1. Full utilization of existing habitat. 2. Prevention of further habitat losses. 3. Restoration and enhancement of fish habitat. 4. Greater care in selecting fish for hatchery reproduction to ensure a wide diversity of genes, and 5. Reduction of impacts of mixing wild and hatchery stocks.

In addition, the following questions evaluate how well state and federal management agencies are achieving a balance in objectives for habitat, harvest, and hatchery management. 1. How much of the resource base has been designated for wild fish management? 2. Is there a programme to inventory and classify discrete wild and hatchery stocks? 3. Have stock transfer constraints been established based on an understanding of stock distribution? 4. Have mixed stock harvest rates been controlled in order to allow adequate escapement of wild stocks? 5. Have breeding and rearing practices developed for hatcheries been based on genetic criteria? 6. Are release numbers and locations for hatchery fish based in part on the need to avoid excessive gene flow into wild populations? 7. What proportion of agency funds and manpower are devoted to habitat protection and development compared to hatchery management and harvest management? This useful volume is available at a cost of $13.95 from: Washington Environmental Foundation, 80 South Jackson, Suite 308, Seattle, Washington 98104, U.S.A.

CRITFC NEWS

(The Newsletter of the Columbia River Inter-Tribal Fish Commission) is published regularly and contains information on salmonid fisheries and fishery problems in western North America. Its editors are Elizabeth South and Laura Berg and it is provided free of charge 'for the 'enhancement' of those who care'. CONTACT: CRITFC, Publications Information Officer, 2705 E. Burnside, Suite 114, Portland, Oregon 97220, U.S.A.

6TH WSW NEWSLETTER

If you have any material for the next Newsletter (deadline 1 July 1984) please send it to P.S. Maitland, Institute of Terrestrial Ecology, 78 Craighall Road, Edinburgh, Scotland.

THE SOUTHWESTERN NATURALIST

DISTRIBUTION, ABUNDANCE, AND HABITAT OF THE ARKANSAS DARTER *ETHEOSTOMA CRAGINI* (PERCIDAE) IN COLORADO

By David L. Miller

VOLUME 29, NO. 4 14 NOVEMBER 1984

THE SOUTHWESTERN ASSOCIATION OF NATURALISTS

President
Hugh H. Genoways (*Mammalogy*)
CARNEGIE MUSEUM OF NATURAL HISTORY
PITTSBURGH, PA 15213

Permanent Secretary
Keith A. Arnold (*Ornithology*)
TEXAS A&M UNIVERSITY
COLLEGE STATION, TX 77843

Managing Editor
Francis L. Rose (*Herpetology*)
DEPT. OF BIOLOGICAL SCIENCES
TEXAS TECH UNIVERSITY
LUBBOCK, TX 79409

Associate Editor, Higher Vertebrates
Brian Chapman (*Ornithology*)
DEPT. OF BIOLOGY
CORPUS CHRISTI STATE UNIV.
CORPUS CHRISTI, TX 78412

Associate Editor, Fishes
John McEachran (*Ichthyology*)
DEPT. OF WILDLIFE & FISHERIES SCIENCES
TEXAS A&M UNIVERSITY
COLLEGE STATION, TX 77843

Associate Editor, Herps
Jerry D. Johnson
DEPT. OF BIOLOGY
EL PASO COMMUNITY COLLEGE
EL PASO, TX 79998

SWANEWS *Editor*
Arthur G. Cleveland (*Mammalogy*)
DEPT. OF BIOLOGY
TEXAS WESLEYAN UNIVERSITY
FORT WORTH, TX 76105

President-Elect
John W. Bickham (*Cytogenetics*)
TEXAS A&M UNIVERSITY
COLLEGE STATION, TX 77843

Treasurer
Fred S. Hendricks (*Vertebrate Systematics*)
DEPT. OF WILDLIFE AND FISHERIES SCIENCES
TEXAS A&M UNIV.
COLLEGE STATION, TX 77843

Secretary
Elizabeth McGhee (*Museum Science*)
UNIV. OF GEORGIA
ATHENS, GA 30602

Associate Editor, Invertebrates
Joseph C. Britton
DEPT. OF BIOLOGY
TEXAS CHRISTIAN UNIVERSITY
FORT WORTH, TX 76129

Associate Editor, Botany
Bonnie Amos (*Plant Taxonomy*)
DEPT. OF BIOLOGY
BAYLOR UNIVERSITY
WACO, TX 76798

Associate Editor, Botany
O. W. Van Auken (*Plant Ecology*)
DIVISION OF LIFE SCIENCES
UNIVERSITY OF TEXAS
SAN ANTONIO, TX 78285

Advertising Editor
Terry L. Yates (*Mammalogy*)
DEPT. OF BIOLOGY
UNIVERSITY OF NEW MEXICO
ALBUQUERQUE, NM 87131

Board of Governors

Class of 1985
Michael Kennedy (*Mammalogy*)
MEMPHIS ST. UNIV.
MEMPHIS, TN 38152
Robert A. Thomas (*Herpetology*)
LOUISIANA NATURE CENTER
UNIVERSITY OF NEW ORLEANS
NEW ORLEANS, LA 70127

Class of 1986
Terry Yates (*Mammalogy*)
UNIV. OF NEW MEXICO
ALBUQUERQUE, NM 87131
Arthur G. Cleveland (*Mammalogy*)
TEXAS WESLEYAN UNIV.
FORT WORTH, TX 76105

Class of 1987
David J. Schmidly (*Mammalogy*)
TEXAS A&M UNIV.
COLLEGE STATION, TX 77843
Michael Mares (*Mammalogy*)
UNIV. OF OLKAHOMA
NORMAN, OK 73019

Class of 1988
William J. Matthews (*Ichthyology*)
UNIV. OF OKLAHOMA BIOLOGICAL STATION
KINGSTON, OK 73439
Troy L. Best (*Ecology, Systematics*)
UNIV. OF NEW MEXICO
ALBUQUERQUE, NM 87131

Founded in May, 1953, to promote the field study of plants and animals, living and fossil, in the southwestern United States, Mexico, and Central America, and to aid in the scientific activities of its members, the Association holds an annual meeting with field trips, and publishes THE SOUTHWESTERN NATURALIST. Membership is open to all persons interested in natural history.

Dues, including subscription to THE SOUTHWESTERN NATURALIST, are $15 per year for regular members and $20 for sustaining members. Institutional and library subscriptions are $25 per year. Make checks or money orders payable to The Southwestern Association of Naturalists and send them to the treasurer. Inquiries regarding back issues should be sent to: Steven W. Kelsch, Dept. Wildlife & Fisheries Sciences, Texas A&M University, College Station, TX 77843. This journal is not available in exchange.

Published quarterly at Lubbock, TX 79409, by The Southwestern Association of Naturalists. Second-class postage paid at Lubbock, Texas.

Postmaster: Please send form 3579 and undeliverable issues to The Southwestern Association of Naturalists, c/o Dept. Wildlife and Fisheries Sciences, Texas A&M University, College Station, TX 77843.

NOTICE TO MEMBERS

All second-class mail must include the ZIP code. If your address does not show your correct ZIP code, please insert the code on the addressed envelope, along with any other corrections, and mail it to the Treasurer.

ISSN 0038-4909

[1984]

form is basically that of the adult. Guts are simple with no elaborations in all species. At hatching *Umbra* has a shorter gut and fewer myomeres than *Esox* and this is reflected in there being 5 myomeres between the yolk sac and the anus in newly hatching *U. pygmaea* and 12 in *E. americanus* (Malloy and Martin, 1982).

RELATIONSHIPS

Malloy and Martin (1982) point out three ontogenetic characteristics shared by *Esox* and *Umbra,* which indicate close relationship. The position of the heart at the time of formation is on the yolk sac anterior to and left of the head. All other fish for which position of the forming heart is noted have it forming under the head in the pericardial cavity or, as in the Atheriniformes, near the midline and anterior to the head. The yolk-sac circulatory pattern consists of paired simple common cardinals, a posterior rete formed by the subintestinal vitelline vein and paired or single hepatic vitelline veins which enter the rete before the subintestinal vitelline vein joins the common cardinals at the heart (see Fig. 74). This differs from all other salmoniform fish for which the pattern is described (Kunz, 1964; Soin, 1966). The oil droplets go through a predictable series of clustering and dispersion. Oil droplet movement of this sort has only been documented previously by Ahlstrom (1968) for bathylagid smelts of the genera *Bathylagus* and *Leuroglossus.*

McDowall (1969) recognized a salmonoid-osmeroid-esocoid lineage but states "Where esocoids fit into this series of suborders and families is not clear to me." Rosen (1973) likewise considers the esocoids and salmonoids to probably be closely related but considers this alignment to be provisional. Fink and Weitzman (1982), in contrast, state that they find no evidence to consider the esocoids closely related to the other Protacanthopterygii (*sensu* Rosen, 1974), which are the Agentinoidei and Salmonoidei (including the Salmonoidea plus Osmeroidea). Fink and Weitzman list the esocoids as *sedis mutabilis* at the euteleostean level or as the sister group to all other euteleosts. Soin (1980), on the basis of egg development patterns, feels that the esocoid fish are incorrectly placed as a suborder of the Salmoniformes, however he gives no guidance as to correct placement. While the ontogenetic evidence presented in Table 30 is not conclusive it suggests that there is a large difference between the esocoids and the Salmonoidei and this is consistent with the opinions of Fink and Weitzman.

The vertebrae of Umbrids have a pronounced anterior constriction, giving them an asymmetrical appearance, however *Novumbra* and *Dallia* show this characteristic only while young and most noticeably in the mid-abdominal region. In *Esox* the vertebrae are either unconstricted or are constricted both anteriorly and posteriorly so that they appear symmetrical (Cavender, 1969). Other differences between the Esocidae and the Umbridae are seen in the Umbridae having nine or fewer branchiostegals, fewer infraorbitals, no supratemporals or intercalars and usually fewer than 41 vertebrae (Wilson and Veilleux, 1982).

CHESAPEAKE BIOLOGICAL LABORATORY, UNIVERSITY OF MARYLAND, BOX 38, SOLOMONS, MARYLAND 20688.

Salmonidae: Development and Relationships

A. W. Kendall, Jr. and R. J. Behnke

SALMONIDS (whitefishes, ciscoes, grayling, trout, and salmon) are highly important in terms of aesthetic appreciation, commercial and recreational value, and scientific study. Studies of the development of salmonids from hatching until the time of yolk depletion, and of the relationships among subfamilies and genera have been largely neglected [see review of systematics by Dorofeyeva et al. (1980)] despite the large body of literature on early embryological development and relationships among species and populations. Salmonids all spawn in fresh or brackish water; some are anadromous while others are strictly freshwater. The family is composed of about 10 genera in three subfamilies: Coregoninae, Thymallinae, and Salmoninae (Table 32) (Nelson, 1976).

Along with a precise homing ability, salmonids tend to form genetically isolated populations. They seem to be able to occupy new niches and habitats as these become available in the cold temperate parts of the Northern Hemisphere. One result of this adaptability is the existence of taxonomic problems mainly at the species-population levels (Utter, 1981).

DEVELOPMENT

Post-hatching development of salmonids has been little studied (Table 33), and only a superficial analysis of comparative developmental stages has been attempted (Soin, 1980). *Thymallus* and the salmonines share apparently advanced features of development such as large yolk sac with an extensive vitelline circulatory system and development of rather uniform intense pigment, while coregonines develop larvae that are more typical of other freshwater fishes (Faber, 1970). *Thymallus* seems intermediate between the coregonines with a "normal" larval stage and the salmonines in which the larval stage is largely bypassed (the young have fully formed fins by the time the yolk is absorbed). Parr marks (vertical blotches or bars of pigment over the trunk of juveniles) are present in all salmonids except *Coregonus* and *Stenodus* but are not seen in juveniles of other fishes. Norden (1961) incorrectly considered the early stages of *Coregonus artedii* as figured by Fish (1932) to be similar to those of *Thymallus arcticus.* He also stated that "the development of

Table 32. Characters that vary among the Salmonid Subfamilies.

Character	Subfamily		
	Coregoninae	Thymallinae	Salmoninae
General			
Genera	*Coregonus, Prosopium, Stenodus*	*Thymallus*	*Brachymystax, Hucho, Salvelinus, Salmo, Parasalmo, Oncorhynchus*
Species	30	4	32
Habitat	freshwater, few anadromous	freshwater	freshwater and anadromous
Egg size	1.8–3.7 mm	2.5 mm	3.7–6.8 mm
Diploid chromosome numbers	64–82	102	52–92
Dorsal fin rays	10–15	17–25	8–12
Dentition[1]			
Tooth character	narrow, sharp, 2–3 sections	uniform in size	vary in size
Maxillary	toothless	toothed	toothed
Dentary	minute teeth restricted to anterior end	narrow, teeth of uniform size all along bone	numerous teeth of varying size all along bone
Vomer	small and toothless (except in *Stenodus* and some *Coregonus*)	small, with teeth	long, with teeth
Premaxillary	small	large	large
Caudal skeleton[2]			
Epurals	3	3	2–3[4]
Stegural	little developed	little developed	well developed
Neural and hemal spine expansion	little	moderate	large
Urodermal	present	absent	absent
Neural spine on PU$_1$	absent	absent	present
Neural spine on PU$_2$	not fully developed	not fully developed	fully developed[4]
Cranial osteology[3]			
Orbitosphenoid	present	absent	present
Suprapreopercular	absent	absent	present
Parietals meet at midline	yes	yes	no
Hypethmoid	present	absent	usually absent
Basisphenoid	usually absent	present	present
Uppermost orbital[5]	present	present	absent

[1] Vladykov (1970).

[2] Cavender (1970).

[3] Norden (1961).

[4] Some variation within Salmoninae in these two characters. Those with 2 epurals usually have most extensive neural spine development.

[5] Sometimes erroneously termed dermosphenotic; sometimes present in Salmoninae; see Behnke (1968, p. 9–10).

the young grayling has much in common with that of both the coregonines and salmonines" (Norden, 1961:743).

Among the coregonines, larvae of *Prosopium* (Faber, 1970; Auer, 1982), *Leucichthys* (Fish, 1932; Faber, 1970; Auer, 1982), and *Coregonus* (Fish, 1932; Faber, 1970; Auer, 1982) have been illustrated and briefly described. All show similar larval morphology (Fig. 75). They are rather slender with a long preanal finfold—the yolk being confined to the anterior trunk region. The yolk-sac length is <35% total length (TL), eye diameter is <7% TL, and body depth at anus is usually <10% TL (Auer, 1982). The yolk is exhausted before any of the fins, except the caudal, possess full complements of rays. *Prosopium* eggs have multiple oil globules, while *Leucichthys* and *Coregonus* eggs have a single oil globule (Auer, 1982). Pigment in preflexion and flexion larvae is mainly associated with the dorsal and ventral midlines. Later, the body becomes more uniformly pigmented. *Prosopium* develops parr marks during the juvenile period. Larvae of *Stenodus* are undescribed and they may differ from those described above, since adults of this genus appear quite divergent from the others in this subfamily.

Early development of *Thymallus thymallus* has been fully described (Penaz, 1975). They hatch with a large, anteriorly placed yolk sac that is covered by a rather extensive vitelline circulatory system, and the preanal and postanal finfolds are about equal in length (Fig. 75). The yolk sac is exhausted during notochord flexion and by that time some fin rays have developed in all of the fins. The larvae are rather heavily pigmented during this period. When the fins have developed their adult complement of rays, the fish appear like juveniles and parr marks begin to form.

Early development of all the salmonine genera and most subgenera is known, although several are inadequately described (Table 33). Described development of all salmonines is quite similar (Figs. 76, 77). Their eggs are among the largest of all teleosts. They all hatch with large yolk sacs and well developed vitelline circulatory systems. The preanal finfold is shorter than the postanal finfold (except in *Hucho* where they are about equal). The preanal finfold extends somewhat down the posterior of the yolk sac in *Oncorhynchus*. The notochord is slightly flexed and some caudal rays are present. Yolk-sac length is

TABLE 33. MERISTIC VALUES AND REFERENCES TO DESCRIPTIONS OF LARVAE OF SALMONIDS. Total reported ranges of meristic values are given, although the extremes of the ranges may be rarely observed.

Subfamily Genus Subgenus	References with illustrations of flexion stage larvae	Ranges of meristic values								Primary source
		Vertebrae[1]	Dorsal fin[2]	Anal fin[2]	Pectoral fin	Pelvic fin	Total gill rakers	Lateral line scales	Branchiostegal rays	
Coregoninae										
Stenodus		64–69	12–19	15–18	16–17	11	19–24	90–110	9–12	Scott and Crossman (1973)
Prosopium	Faber (1970), Auer (1982)	50–65	10–15	10–14	13–18	9–12	11–44	50–108	6–10	Scott and Crossman (1973)
Coregonus										
Leucichthys	Fish (1932); Faber (1970), Auer (1982)	50–67	8–15	9–16	13–18	8–13	21–64	58–110	7–10	Scott and Crossman (1973)
Coregonus	Fish (1932), Faber (1970), Auer (1982)	55–64	10–13	9–14	14–17	11–12	15–78	70–102	6–10	Scott and Crossman (1973)
Thymallinae										
Thymallus	Penaz (1975)	58–62	17–25	11–15	14–16	10–11	16–33	81–103	7–9	Scott and Crossman (1973)
Salmoninae										
Brachymystax	Smol'yanov (1961)	58–62	12–15	11–14	15–18	9–10	20–30	120–150	10–13	Behnke (1968) and original
Hucho										
Hucho	Balon (1956)	64–71	12–14	11–13	15–18	10	10–17	120–150	9–12	Behnke (1968) and original
Parahucho		57–62	12–14	12–14	14–17	9	14–20	110–120	9–12	Behnke (1968) and original
Salvelinus										
Salvelinus	Balon (1980)	57–71	10–12	8–10	14–16	9–11	11–51	105–152	10–15	Scott and Crossman (1973)
Baione	Balon (1980), Auer (1982), Martinez (1983)	57–62	10–14	9–13	11–14	8–9	14–22	110–130	9–13	Scott and Crossman (1973)
Cristivomer	Fish (1932), Balon (1980), Auer (1982)	61–69	8–10	8–10	12–17	9–10	16–26	116–138	10–14	Scott and Crossman (1973)
Salmo										
Salmo	Auer (1982), Martinez (1983)	54–62	10–15	8–13	12–16	9–10	14–25	100–130	10–12	Behnke (1968) and original
Salmothymus		56–60	13–15	11–13	12–14	9–10	25–32	100–115	10–12	Behnke (1968) and original
Acantholingua		52–59	11–13	10–12	11–13	9–10	18–22	95–110	9–11	Behnke (1968) and original
Platysalmo		57–59	13	11	14	9	23–24	109–110	10–11	Behnke (1968) and original
Parasalmo	Auer (1982), Martinez (1983)	55–67	8–12	8–12	11–17	9–10	14–28	100–150	9–13	Scott and Crossman (1973)
Oncorhynchus	Auer (1982)	61–75	9–16	12–19	11–21	9–11	18–43	120–160	11–19	Scott and Crossman (1973)
	Overall ranges	50–75	8–25	8–19	11–21	8–13	10–78	50–160	6–19	

[1] Variations exist in the literature in how many of last 3 upturned vertebrae are counted; some authors omit the last 3 upturned vertebrae.

[2] Includes rudiments where specified. A variation of 2–3 rays may result from different methods of counting (whether unbranched or rudimentary rays are included).

>35% TL, eye diameter >7% TL, and body depth at anus usually >10% TL (Auer, 1982). Pigmentation is uniformly heavy at hatching or later in the yolk-sac stage. The median fins develop rays before the paired fins. By the time the yolk is absorbed the finrays have completed formation and the fish takes on a juvenile appearance. Thus, the yolk remains a source of nutrition throughout the larval stage.

RELATIONSHIPS

Although salmonids are considered to be living representatives of the basal stock from which euteleostean evolution proceeded, there is no clear consensus on their relationships to other fishes. Since there are differing opinions on the relationships between the major teleostean lineages (i.e., the divisions of Greenwood et al.; 1966), it is difficult to select representatives of outgroups to compare with the salmonids. Recent studies (Rosen, 1974; Fink and Weitzman, 1982; Fink, this volume) have pointed out that the Protacanthopterygii and even the Salmoniformes are probably not monophyletic taxa. The salmonids along with the galaxioids, osmeroids, and argentinoids, may form a group (Salmonae) that is the primitive sister group of the neoteleostei. However, the relationships among these groups is not clear, and the salmonids may be closer to the neoteleostei than to these other groups with which they have frequently been aligned (Fink and Weitzman, 1982; Lauder and Liem, 1983; Fink, this volume). Some primitive teleost traits

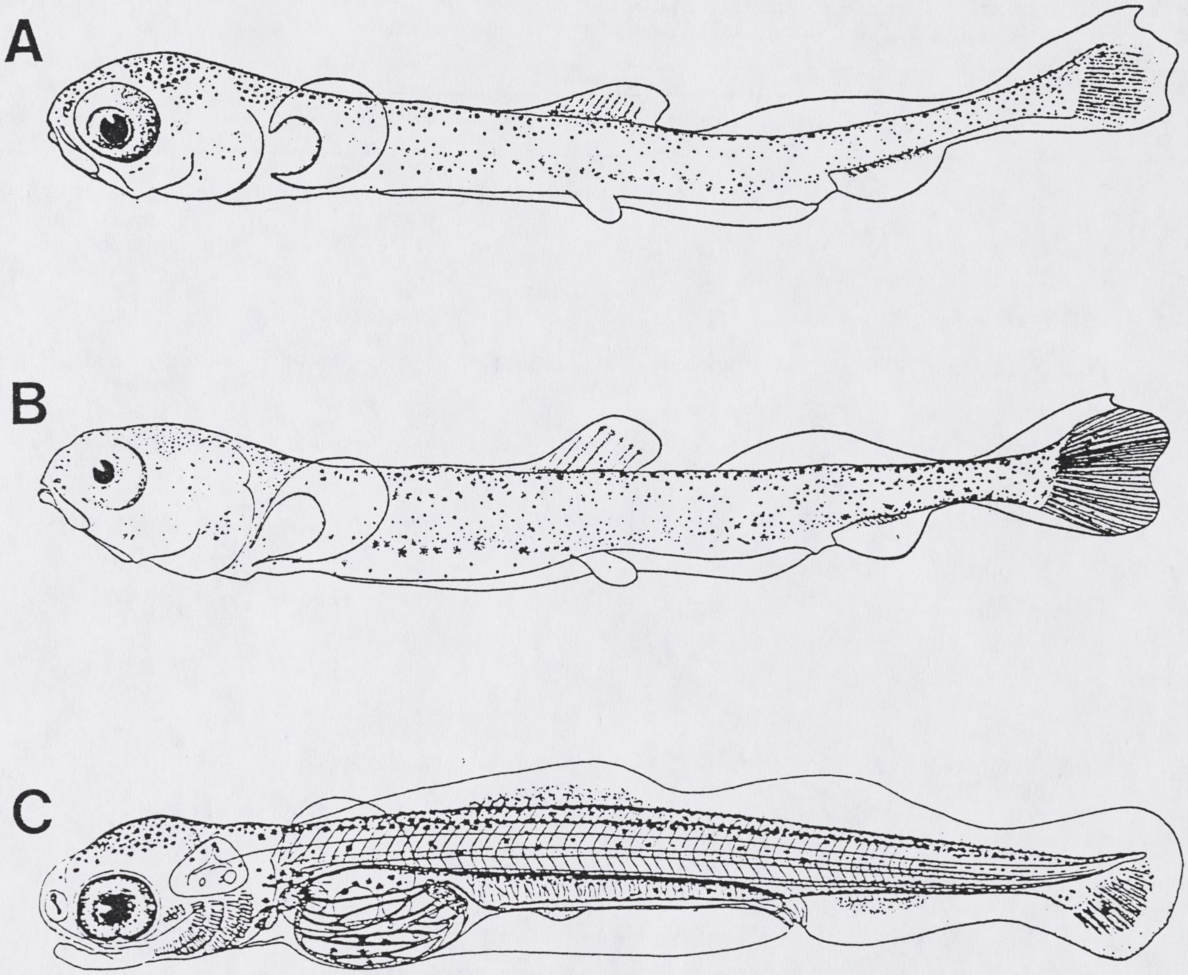


Fig. 75. Flexion stage larvae of: (A) *Coregonus* (*Leucichthys*) *artedii* (17.5 mm); (B) *Coregonus* (*Coregonus*) *clupeaformis* (18.5 mm); (C) *Thymallus thymallus* (16.0 mm). A and B from Fish (1932), C from Penaz (1975).

Table 34. Characters that vary among the Coregonine Genera and Subgenera (sg) mainly from Norden (1961) and Cavender (1970).

	Coregonus			
Character	*Coregonus* (sg)	*Leucichthys* (sg)	*Prosopium*	*Stenodus*
Species	8	17	7	1
Habitat	Some occasionally anadromous	Several anadromous	Freshwater	Anadromous
Basibranchial plate	Absent	Absent	Present	Absent
Parietal bones meet along midline	Yes	Yes	Yes	No: narrowly separated
Postorbitals in contact with preopercle	Yes	Yes	Yes	No
Parr marks	Absent	Absent	Present in some	Absent
Flaps between nostrils	2	2	1	2
Mouth size	Small	Moderately large	Small	Large
Teeth	Weak or none	Weak or none	Weak or none	Many, small
Mouth position	Subterminal	Superior or terminal	Subterminal	Terminal
Vomer	Small, toothed in some	Small, toothed in some	Small, toothless	Large, toothed
First supraorbital	Moderate	Moderate	Short	Long
Supraethmoid	Short	Short	Long	Short

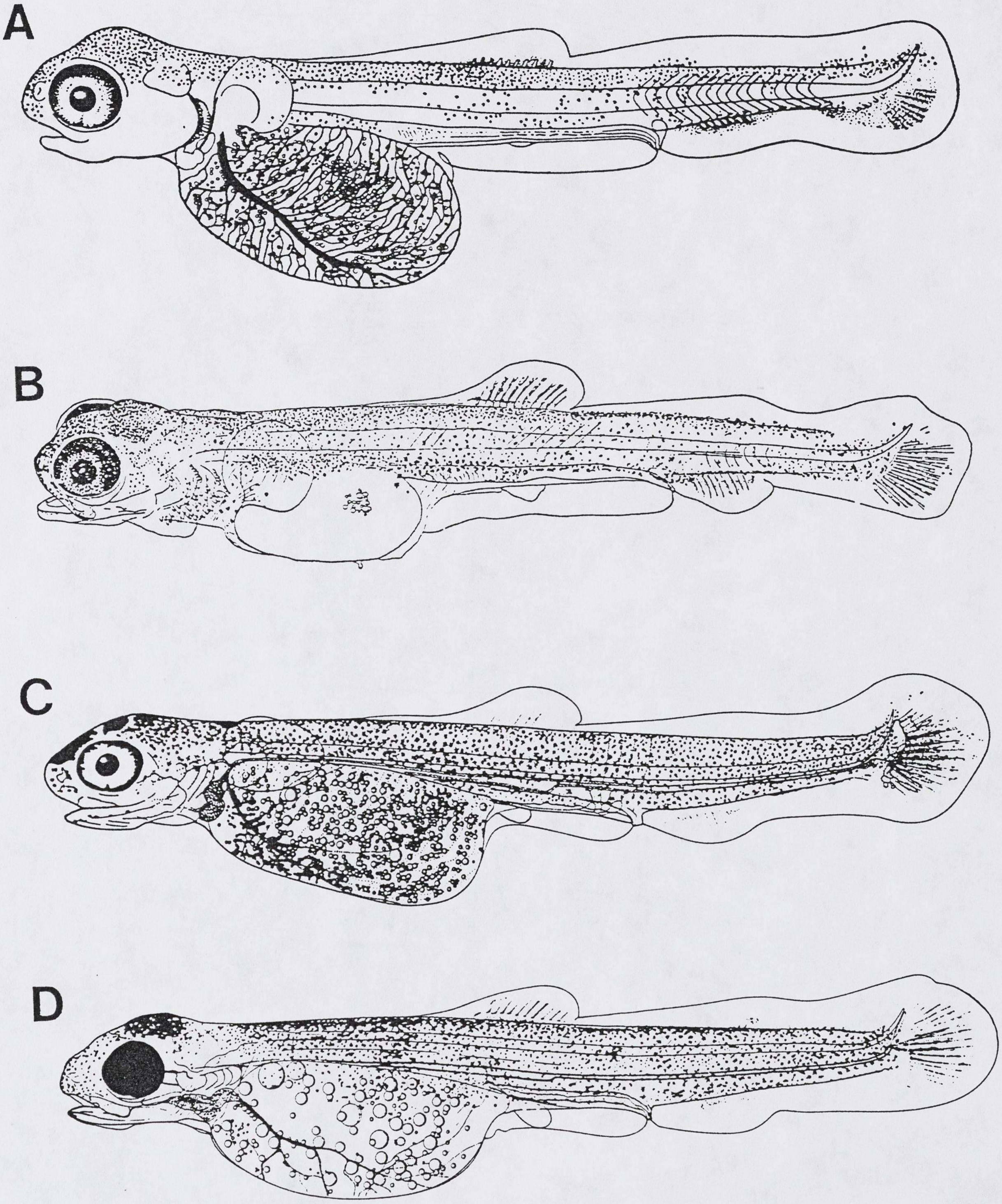
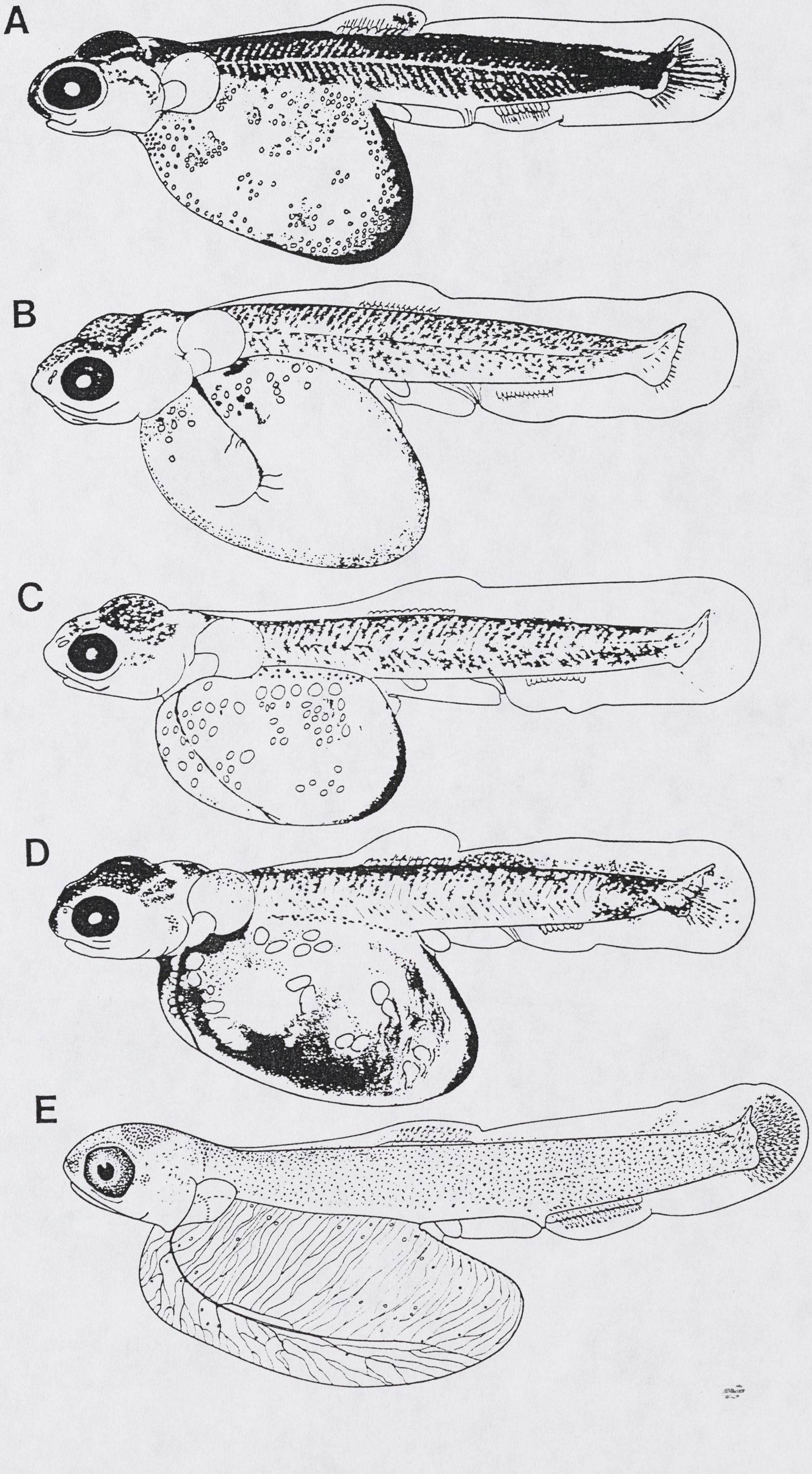


Fig. 76. Flexion stage larvae of: (A) *Brachymystax lenox* (17.2 mm); (B) *Hucho* (*Hucho*) *hucho* (20.8 mm); (C) *Salvelinus* (*Salvelinus*) *alpinus* (19.8 mm); (D) *Salvelinus* (*Cristivomer*) *namaycush* (approx. 20.4 mm). A from Smol'yanov (1961), B from Balon (1956), C and D from Balon (1980).

→

Fig. 77. Flexion stage larvae of: (A) *Salvelinus* (*Baione*) *fontinalis* (14.0 mm); (B) *Parasalmo gairdneri* (14.0 mm); (C) *Parasalmo clarki* (14.2 mm); (D) *Salmo trutta* (14.0 mm); (E) *Oncorhynchus tshawytscha* (25.0 mm). A–D from Martinez (1983), E original.


A
B
C
D
E

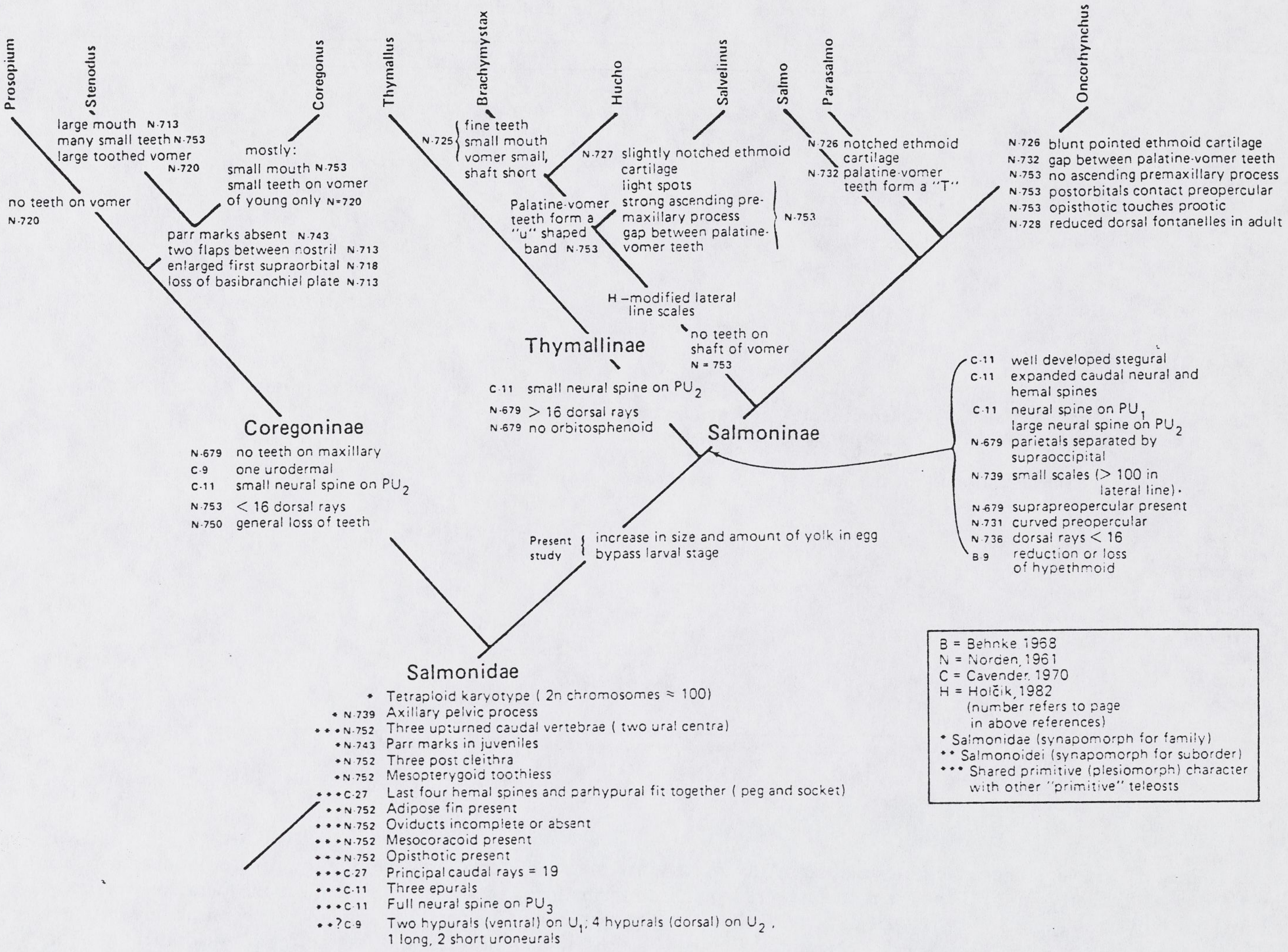


Fig. 78. Hypothesis of relationships among extant salmonid genera. Groupings and branching points are based largely on a consensus of recent literature and are not the result of a strict cladistic analysis.

possessed by salmonids include lack of oviducts, presence of abdominal pores, and three upturned caudal vertebrae supporting the hypurals. Salmonids are autapomorphic with about twice the DNA content of other "salmoniform" families, apparently the result of having a common tetraploid ancestor. The salmonids possess an adipose fin, a mesocoracoid, pyloric caeca, and the vestige of a spiral valve intestine. The gill membranes extend far forward free from the isthmus and there is a pelvic axillary process. Two shared derived features of the salmonids and neoteleostei are: 1) the articulation of both the basioccipital and exoccipital with the first vertebra, and 2) the presence of a medial cartilage between the ethmoid and premaxilla (Fink and Weitzman, 1982).

Although it is not possible at present to perform a meaningful cladistic analysis of the salmonids, some evidence is available in the literature which can contribute to such an analysis (Fig. 78). Cavender (1970) compared the osteology of leptolepids, extinct fish thought to represent the basal teleost condition, with that of the salmonids. He found several characters that indicated 1) that the salmonids are monophyletic, and 2) how the three subfamilies of salmonids are interrelated. The coregonines appeared to be most similar to the leptolepids, the thymallines more derived than the coregonines, and the salmonines more derived than the thymallines. Reshetnikov (1975), on the basis of several types of characters, suggested elevating the subfamilies to familial status.

Coregoninae contains about 30 species in three genera. They are mainly freshwater, and produce rather small eggs, compared to those of the other two subfamilies. They share several advanced characters with the other subfamilies, indicating that salmonids are monophyletic, but lack a number of advanced character states possessed by the other two subfamilies, as these branched off after the coregonines. Within the coregonines, *Prosopium* seems least diverged (Table 34). *Stenodus* shows several, possibly secondarily derived character states concordant with feeding on large active prey (expanded dentition, large mouth). *Coregonus*, which seems to be a sister group to *Stenodus*, is separated into two subgenera: *Leucichthys* with adaptations for plankton feeding, and *Coregonus* which are mainly benthic feeders.

Thymallinae contains one genus, *Thymallus*, with about four species in freshwater of the colder parts of the Northern Hemi-

TABLE 35. Characters that vary among the Salmonine Genera.

Characters	*Brachymystax*	*Hucho*	*Salvelinus*	*Salmo*[1]	*Parasalmo*[1]	*Oncorhynchus*[1]
Subgenera		*Hucho, Parahucho*	*Salvelinus, Baione, Cristivomer*	*Salmo, Salmothymus, Acantholingua, Platysalmo*		
Species	2	3–5	8	8	5	6
Habitat	freshwater	freshwater and anadromous	freshwater and anadromous	freshwater and anadromous	freshwater and anadromous	usually anadromous
Mouth size	small	large	large	large	large	large
Teeth on shaft of vomer	no	no	no	yes	yes	yes
Palatine-vomerine teeth	U-shaped band	U-shaped band	teeth narrowly separated	teeth narrowly separated	teeth narrowly separated	teeth widely separated
Postorbitals contact preopercle	no	no	no	no	no	yes
Supraethmoid shape	long, with numerous posterior projections	broad, with numerous short posterior projections	long, with numerous posterior projections	notched posteriorly	notched posteriorly	deeply notched posteriorly
Ascending premaxillary process	intermediate sized	intermediate sized	extended and well developed	intermediate sized	intermediate sized	none
Opisthotic touches prootic	no	no	no	no	no	yes
Dorsal fontanelles	persistent	persistent	persistent	persistent	persistent	reduced in adult[2]
Egg size	4–5 mm	large	4–5 mm	5–7 mm	large	large
Diploid chromosomes	92	84	78–84	56, 80–82[3]	56–70	52–74
Dark spots-light background	yes	yes	no	yes[4]	yes	yes

[1] There is lack of agreement on the relationships between these taxa; e.g., some consider *Parasalmo* a subgenus in *Salmo*, while others would also consider *Oncorhynchus* a subgenus of *Salmo*.
[2] Retained in *O. masou*.
[3] *Salmo salar* has 56–60 diploid chromosomes.
[4] *Salmo marmoratus* and *S. platycephalus* have no dark spots.

sphere. They have several character states that seem advanced over those seen in coregonines. They are moderate-sized, generalized insectivores (Table 32).

Salmoninae contains four to six genera, depending on opinions over the relationships among the species in *Salmo, Parasalmo,* and *Oncorhynchus* (Table 35). These seem to be the most advanced of the salmonids, and share several character states that are derived compared to the other two subfamilies (Table 35). Holcik (1982) presented evidence which suggests that the genera *Hucho, Brachymystax,* and *Salvelinus* form one lineage; *Parasalmo* and *Salmo* another; and *Oncorhynchus* a third. Salmonines are mainly active predators and most tend toward an anadromous life history.

Early life history and developmental information should contribute to the rigorous analysis of characters that will be required to validate the foregoing hypotheses about relationships. Such information is not presently available in the literature, but should be readily obtainable, since so many of these fishes are routinely reared in laboratories and hatcheries. Developmental information seems particularly promising in this family, since a wide range of the life history patterns are present and larvae can be superficially grouped according to their representative subfamilies.

(A.W.K.) NORTHWEST AND ALASKA FISHERIES CENTER, 2725 MONTLAKE BLVD. E., SEATTLE, WASHINGTON 98112 AND (R.J.B.) DEPARTMENT OF FISHERY AND WILDLIFE BIOLOGY, COLORADO STATE UNIVERSITY, FORT COLLINS, COLORADO 80523.

Journal of Beijing Normal University (Natural Science) 3:85-90,1984

北京师范大学学报 1984年 第三期

黄鳝的姊妹染色单体分化染色(SCD)、互换(SCE)及点染色体(DC)*

刘凌云

（生物系）

1973年Latt应用BUdR-Hoechst荧光技术，在培养的人淋巴细胞染色体显示出SCD，检查了SCE。此后，在一些实验室不断改进、建立SCD方法，应用于细胞生物学、细胞遗传学、环境毒理学、医学等各领域。在检测环境诱变剂和致癌剂方面，SCE分析技术有着重要意义。现在一般认为，SCE技术是检测环境诱变剂对DNA损伤修复的一种灵敏的手段。

关于这方面的研究，主要应用人和哺乳动物细胞以及少数的其它动物细胞，而对鱼类染色体SCE的研究极少。黄鳝染色体的G-带带型已有研究[1]，但对其SCD与SCE，国内外尚未见报道。黄鳝染色体数目少，个体大，全部为端着丝点染色体，便于观察分析，而且黄鳝的生活能力较强，看来有可能是检测水体污染物的好材料，因此进行如下基础工作。

材料和方法

材料来源：黄鳝购自北京郊区万泉庄渔场，部分购自北京西四副食商店。每次购置的鱼均在室内饲养3—6个月后再进行实验。共做了15条鱼，鱼体长为48—63厘米。

细胞培养、染色体制片：基本上同作者以前的工作[2-3]。培养基用RPMI 1640（日本），不同的是将黄鳝的淋巴细胞接种于培养瓶内，置于29℃温箱培养24小时，加入BUdR 8—10微克/毫升，避光培养2个细胞周期。在培养结束前1.5—2小时加入秋水酰胺，最终浓度为0.1微克/毫升，空气干燥制片。

姊妹染色单体分化染色：主要参考〔4〕的FPG法和〔5〕的磷酸盐热处理法(B-G法)，修改为适于鱼类染色体显示SCD的方法，并参考〔6〕的方法观察了点染色体。具体方法：①FPG法：将染色体标本用1微克/毫升的Hoechst-33258荧光染料（用Sörensen液配制，pH=7.0）染色30分钟，用双蒸水漂洗，将玻片置于恒温水浴箱上的培养皿内预热至32—35℃，在玻片上加2×SSC溶液，载片上不加盖片，30瓦紫外灯（220V）距玻片标本6厘米处照射30分钟，用双蒸水洗去2×SSC溶液，Giemsa染色10—15分钟。②B-G法：将玻片标本在38—40℃下烤3小时，置于预热至70℃的1M NaH_2PO_4溶液(pH=8.0，用NaOH

本文1984年2月28日收到。

* 周小燕和狄少杰同志参加实验工作。

调节）中处理5—20分钟后，用双蒸水洗，Giemsa染色15分钟。B-G法虽也能获得较好结果，但不及FPG法稳定。③点染色体处理方法，与B-G法基本相同，只是1M NaH_2PO_4溶液的pH≥9，温度为70—75℃。

SCE的计数：在40倍物镜下初步辨认有无SCE，并计数染色体数目，然后在油镜下对染色体2n＝24、分散及形态良好、SCD清晰的分裂相进行观察，计数SCE数。如果在两条染色单体之间出现一次交换，计为一个SCE，出现两次交换计为两个SCE，余类推。我们统计了8条鱼339个分裂相的SCE，每个个体最少观察统计30个SCD清晰的分裂相。

结果和讨论

用上述FPG法与B-G法显示出黄鳝染色体的SCD和SCE（图1—3），并以FPG法显示人染色体的SCD和SCE（图5）与之对比。鱼类与哺乳类染色体同样在含有BUdR的培养基中，经两个细胞周期后，其染色单体的DNA双链，由于BUdR作为核苷酸前体掺入新合成的DNA链中，取代胸腺嘧啶核苷所占的位置，因此改变了DNA的化学组成及染色单体的染色特性。其中一条染色单体DNA双股都掺入BUdR（“BB”染色单体），另一条染色单体DNA双链只有一股掺入BUdR（“TB”染色单体）。关于掺入BUdR后用Giemsa染色显示SCD的详细机理，尚不清楚。由于不同作者采用不同技术都得到了满意的SCD制片，因此曾有不同解释。通常认为BB染色单体螺旋化程度降低，从而影响了与Giemsa染料的亲和力，所以染色较浅。文献〔7〕比较分析了显示SCD的不同技术，提出BUdR取代的染色单体，在某些条件下，经过预先的致敏作用，能够自发地进行光解，荧光染料可作为这种致敏剂。BUdR取代染色单体，也可在光线或紫外线照射后直接发生组织结构变化。在某些处理条件下，玻片经过高温或是胰酶消化处理，也能发生组织结构的变化。BUdR掺入染色单体分化染色的程度，看来主要与组织结构变化的程度有关。关于SCE的形成，通常认为是姊妹染色单体断裂愈合的结果，但具体机理尚待进一步研究。

经统计分析8条鱼的中期分裂相所显示的SCE频率，结果见表1、图3。

表1　黄鳝淋巴细胞染色体的SCE频率

实验鱼编号	观察中期相数	SCE数/染色体数	SCE数/染色体	SCE数/中期相
1	45	12/1080	0.011	0.267
2	74	10/1776	0.006	0.136
3	30	10/720	0.014	0.333
4	31	13/774	0.017	0.419
5	31	12/774	0.016	0.387
6	30	17/720	0.024	0.567
7	56	16/1344	0.012	0.286
8	42	9/1008	0.009	0.214
总计	339	99/8136		
平均			0.014±0.005	0.326±0.133($\overline{X}$±SD)

从表1可以看出，SCE的频率范围为0.136—0.567，对不同的鱼有所差别，相差1.5—4

倍多不等．这可能与各条鱼的遗传背景以及原来所处的生活环境不同有关．由于SCE对一些物理、化学以及生物因素的作用很敏感，因此在不同环境中，一些已知和未知的各种因子都会影响SCE的频率．我们的材料购自菜市场和渔场，来源不同，虽然经过了３—６个月的饲养时间，对这些差异会有所调正，也仍然表现出不一致，但是总的来看，SCE频率一般处于较低水平．

文献〔８〕曾做过泥荫鱼(Umbra limi)体内的SCE自发频率，肠组织细胞者为2.64±2.13，鳃者为2.42±1.86，总的为2.59±1.42，每条染色体为0.12．〔９〕又报道以诱变剂诱发体内SCE．他们前后的工作表明SCE频率变化为2.0—4.5/中期相．〔10〕报道生有菜花肿瘤（Cauliflower tumor）的欧洲鳗鲡（Anguilla anguilla）的培养淋巴细胞的SCE，健康的对照鱼的SCE/中期相为1.75±0.18，生肿瘤的病鱼的SCE/中期相为3.84±0.36，还提出欧洲鳗鲡SCE的基线显著的低于人类的．文献〔９〕等做的是体内的SCE，我们做的是培养细胞体外的SCE，〔11〕的工作发现体内SCE数较体外条件的为低，甚至可低一半，这可能是由于代谢排泄等因素的综合影响或BUdR不同分布的结果[8]．我们的实验结果都比泥荫鱼及欧洲鳗鲡等的SCE频率为低．

与人和哺乳动物体外的自发SCE比较见表２．关于人外周血淋巴细胞及其它细胞系和中国仓鼠的细胞系作为检测诱变剂的系统显示SCE的报道很多，例如〔12—17〕．从表２可见，黄鳝的自发SCE频率低于人和中国仓鼠的．对人的外周血淋巴细胞各作者所获得的数据很不一致，这可能是各作者所使用的BUdR浓度不同，检查对象的年龄、性别、遗传背景不同以及代谢类型的差异所致[18]．黄鳝染色体自发的SCE数在个体间有差异的原因可能有许多类似上述之处，但比人和中国仓鼠的低限还要低，这可能也与鱼类染色体短小有关．

表２　黄鳝与人、中国仓鼠体外的SCE自发频率比较

细胞		BUdR剂量 (μg/ml)	SCE数/中期相	SCE数/染色体	作者
人淋巴细胞		3	5.74±0.41	0.125	吴旻等1979〔12〕
		3	6.86±0.65		Athanasiou等1980〔13〕
		6	4.41±0.72		CuiMeiying等1982〔14〕
		15	3.92±0.17		Newman等 1982〔15〕
中国仓鼠	成纤维细胞株	15	6.86±1.05		李昌本等1979〔16〕
	卵巢细胞	0.077—6.1	7.9—15.2	0.36—0.69	Wolff等1974〔17〕
黄鳝		8—10	0.326±0.133	0.014±0.005	刘凌云　1983

关于BUdR对SCE形成频率的效应，〔17〕曾报道，随着BUdR浓度的增加而增加，并达到一个稳定的值．然而〔19〕和〔20〕报道，低浓度的BUdR有一恒定的频率，随后在高浓度时才增加．近年来，〔21〕的工作表明，SCE频率是BUdR的函数，与频率增加基本上呈线性关系；但是没有发现在BUDR的低浓度下有一恒定的频率，这种低浓度下的频率被视为自发频率．我们所用的浓度基本上属于低浓度的，SCE频率是属于低水平的，可以认为是自发频率．

在我们的实验中，用NaOH调节磷酸二氢钠pH≥9时出现了点染色体（见图4）.〔6〕

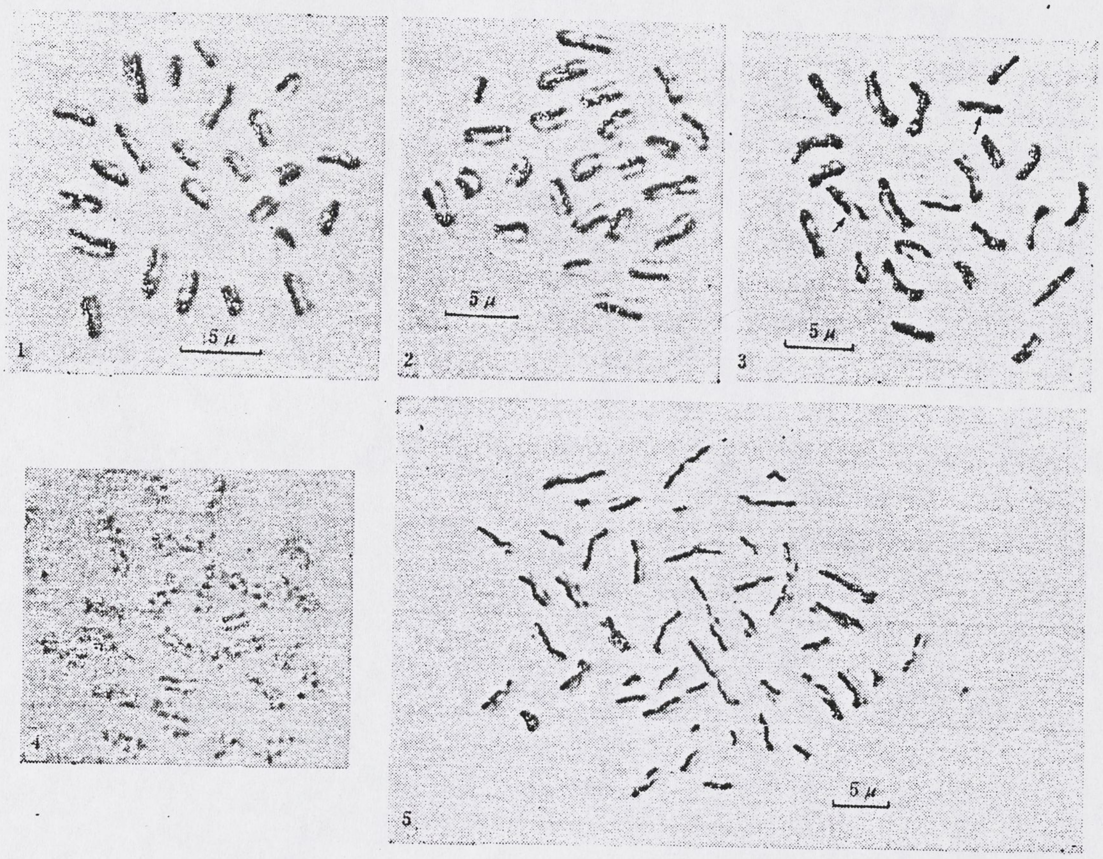


图 1—4　黄鳝淋巴细胞中期相示SCD（图1，FPG法，图2，B-G法）、SCE（图3箭头所指，FPG法）和点染色体（DC，图4）

图 5　人（女）淋巴细胞中期相用FPG法显示SCD和SCE

曾报道，用$NaHCO_3$过饱和的磷酸钠溶液处理中国仓鼠细胞获得了点染色体，并初步认为染色体点型相当于G-带带型．但在鱼类尚未见有点染色体的报道．〔6〕指出用具有过饱和的$NaHCO_3$（pH≥9）的磷酸钠溶液是使染色体形成点的必要条件，用NaOH调pH≥9没发现点染色体．我们的实验正是以NaOH调节pH时出现了点染色体．〔6〕还指出，点染色体形成所需要的温度总是高于显示SCD的温度，并认为它可作为显示SCD所需合适温度的重要指标．他们显示点染色体的温度为80—95℃，我们则用70—75℃．用热的磷酸盐法显示SCD，对哺乳动物及人一般需用80—89℃，而对鱼类染色体我们只用70℃．上述这些差异或许反映了鱼类染色体结构与哺乳动物染色体有微细的差异．至于点的性质及点染色体形成的机理，尚需进一步研究．

通过实验，已知黄鳝染色体的SCE自发频率较低．因此，我们感到分析黄鳝染色体的SCE，在检测诱变剂特别是水体污染物对DNA损伤等有可能是一个有用的手段或指标．

参考文献

〔1〕 刘凌云，遗传学报，**10**(1983),3:230—234.

〔2〕 刘凌云，动物学报，**26**(1980)，2:126—131.

〔3〕 刘凌云，北京师范大学学报（自然科学版)，1981，3:79—83.

〔4〕 Perry, P. and wolff, S., *Nature*, **251**(1974)，256—258.

〔5〕 Korenberg, J. and Freedlender, E., *Chromosoma*,**48**(1974)，355—360.

〔6〕 Wang, H. C. and Mukerji, S., *ibid.*, **58**(1976)，263—267.

〔7〕 Schvartzman, J. B. and Cortes, F., *ibid.*,**62**(1977), 119.

〔8〕 Kligerman, A. D. and Bloom, S. E., *ibid.*,**56**(1976), 101—109.

〔9〕 Kligerman, A. D., *Mutation Res.*, **64**(1979),205—217.

〔10〕 Park, E. H. and Grimm, *H.*, *Cancer Genet. and Cytogenet.*, **5**(1982)，137—145.

〔11〕 Latt, S. A., et al., in *Handbook of Mutagenicity Test Procedures*, Eleevier/North-Holland Biomedical Press, 1977, 275—291.

〔12〕 吴旻、王秀琴，实验生物学报，**12**(1979)，1:31—36.

〔13〕 Athanasiou, K. and Bartsocas, C. S., *Mutation Res.*, **79**(1980), 79—80.

〔14〕 Cui Meiying,et al., *ibid.*, **105**(1982)，195—200.

〔15〕 Newman, S. M., et al., *ibid.*, **101**(1982)，67—75.

〔16〕 李昌本等，实验生物学报，**12**(1979)，2:131—136.

〔17〕 Wolff, S. and Perry, P.,*Chromosoma*, **48**(1974),341—353.

〔18〕 Kato, H., *Int. Rev. Cytol.*, **49**(1977)，55—97.

〔19〕 Kato, H., *Nature*, **251**(1974),70—72.

〔20〕 Tice, R., et al., *Exp. Cell Res.*, **102**(1976),426—428.

〔21〕 San Sebastian, J. R., et al., *Cytogenet. Cell Genet.*, **28**(1980), 47—54.

SISTER CHROMATID DIFFERENTIATION (SCD), SISTER CHROMATID EXCHANGES (SCE) AND DOTTED CHROMOSOMES (DC) IN RICE-FIEID EELS(*MONOPTERUS ALBUS* ZUIEW)

Liu Lingyun

Abstract

SCD and SCE in cultured lymphocytes of *M. albus* were demonstrated by modified FPG and B-G techniques. Dotted chromosomes were observed. The SCE frequency of 339 metaphases in 8 fishes was calculated and statistic analysis showed that the spontaneous frequency of SCE is very low, 0.326±0.133/metaphase. Comparing with SCE frequency of human and Chinese hamster, the SCE spontaneous frequency in rice-field eels is low. Moreover, as the chromosome number is fewer, the chromosome dimension larger and all of them are terminal centric chromosomes, the author feels that SCE analysis in *M. albus* may be as a tool to assay the mutagens, especially to study potentially dangerous water-born chemicals.

Developing Strategies for Rangeland Management

A Report Prepared by the Committee on
Developing Strategies for Rangeland Management

National Research Council /
National Academy of Sciences

Board on Agriculture and Renewable Resources,
Commission on Natural Resources,
National Research Council

Westview Press / Boulder and London

Westview Special Studies in Agriculture Science and Policy

Published in 1984 in the United States of America by Westview Press, Inc.,
5500 Central Avenue, Boulder, Colorado 80301; Frederick A. Praeger, Publisher

Library of Congress Catalog Card Number: 84-51389
ISBN: 0-86531-543-4

Composition for this book was provided by the authors
Printed and bound in the United States of America

10 9 8 7 6 5 4 3 2 1

Impacts of Grazing on Wetlands and Riparian Habitat

William S. Platts and Robert F. Raleigh

ABSTRACT

This article discusses a paper presented by Jon Skovlin at the workshop on "The Impacts of Grazing Intensity and Specialized Grazing Systems," held in El Paso, Texas, in March 1981. Further, it expands on the function and value of riparian-systems, on grazing systems and their effects, and on management alternatives available.

INTRODUCTION

Management of livestock grazing on public lands is an issue of major concern to the users of these lands. We commend the U.S. Department of the Interior (USDI), Bureau of Land Management (BLM), and the National Science Foundation for convening this workshop to examine the issue and continue the efforts toward better grazing management. Likewise, we commend Jon Skovlin for the excellent job he did on his state-of-the-art paper on the "Impacts of Grazing on Wetlands and Riparian Habitat," that we have been assigned to discuss. We believe that Skovlin's report is the best and most comprehensive review compiled to date. Our discussion will be based on the following objectives:

(a) To discuss the values and economics that will influence the future of riparian habitats;

(b) To review the literature for definitions and descriptions of wetlands and riparian habitats;

William S. Platts is Research Fishery Biologist, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Boise, Idaho 83702.
Robert F. Raleigh is Fishery Biologist, U.S. Fish and Wildlife Service, Habitat Evaluation Procedures Group, 2625 Redwing Road, Fort Collins, Colorado 80526.

(c) To report on grazing study results that have been conducted within wetland and riparian environments and;

(d) To present management options available as a result of this knowledge.

Skovlin has adequately addressed objectives (a) and (b) at our present level of knowledge. Our discussion will cover all objectives, but will focus primarily on expanding his treatment of objectives (c) and (d).

There is a great deal of concern over the effects of grazing on riparian habitats, as is evidenced by the abundance of studies the author has reported. He has reservations concerning the quality of some studies he reviewed because he felt that they were poorly designed and results were loosely documented. Riparian-fisheries management studies and some grazing related studies tend to be deficient in one or more of the following components:

(a) Adequate experimental design with comparative before-the-fact or control data;

(b) A frequency and precision of measurement that is sufficient to statistically support the conclusions; and

(c) Adequate definition of grazing intensity, seasons, utilization, and animal distributions.

We also share this concern and, as a result, our review is comprehensive, but conservative. Hopefully, we report study results in a constructive manner that will benefit Scovlin's well done review.

FUNCTION AND VALUE OF RIPARIAN-STREAM SYSTEMS

About 48% of the total land area of the 11 western States is under public ownership and management, and 80% of this land (288 million acres [116.6 million ha]) is being grazed by domestic livestock. These same public lands contain about 250,000 miles (402,250 ha) of streams and over 5 million surface acres (2.0 million ha) of lakes and reservoirs. The BLM alone manages 778,000 acres (314,857 ha) of riparian habitat and 330,000 acres (113,551 ha) of wetland habitat in the lower 11 western States.

Though riparian areas constitute only a fraction of the total land area, they are more productive in terms of both plant and animal species diversity and biomass per unit area than the more arid remainder of the land base. The economic importance of the riparian zone to livestock production is generally well recognized. The fact that riparian habitats are also a key component in the maintenance of healthy populations of fish and wildlife has not been adequately recognized by land managers. A major portion of our self-sustaining populations of western fishes, song birds, big game, upland game, and waterfowl is directly dependent upon the proper management of these riparian/aquatic ecosystems. Of 363 terrestrial wildlife species known to occur in the Great Basin of southeastern Oregon, 288 are either directly dependent on riparian zones or use them more than other habitats (Thomas et al. 1979).

One of the major benefits of a high quality, productive stream is its ability to produce and maintain viable stocks of fishes. Over 60 million people in the United States engage in some form of freshwater sport, commercial or personal use (e.g., Indian) fishery each year. Fishing activities and allied businesses, such as boats, motors, fishing tackle, and tourism associated with fishing, support a multimillion dollar complex of businesses and industries in each western State. Annual sport fishing license sales alone bring $5 million yearly to the State of Colorado, and about $175 million to the nation. It is good business to maintain clean, productive streams, and proper management of the riparian zone is a major key.

A recent economic evaluation of the producing habitat of the chinook salmon (Oncorhynchus tshawytscha [Walbaum]) on the Challis Planning Unit (375,380 acres [151,916 ha]) in Idaho yielded an estimated annual net revenue of $77,100 from chinook salmon alone (USDI-BLM 1976). Steelhead trout (Salmo gairdneri Richardson) stock present is equally valuable, and the same streams support resident stocks of trout with an unreported sport fishery value. Similar figures can be compiled for this unit on the economic value of riparian areas for other wildlife species. Thus, a small unit of land can have large wildlife-fishery values because of the products being generated in the riparian-stream systems.

GRAZING SYSTEMS AND EFFECTS

Skovlin centers his attention on the mountain meadow ecosystem, of which there are over 4 million acres (1.6 million ha) in the 11 western States. We will expand the scope to include some specific results on the various riparian/ stream ecosystems located over the entire 288 million grazing acres (116.6 million ha) administered by Federal agencies.

Scovlin found abundant information on the effects of grazing systems and intensities on plant communities, livestock production, and watershed response (not including streams), but little on riparian habitat response. To date, we have found there are few reported studies that identify how any present cattle grazing strategy will adequately restore riparian habitats in a reasonably acceptable time frame.

The author identifies direct effects of livestock grazing as:

(a) Higher stream temperatures from lack of sufficient woody streamside cover;

(b) Excessive silt (sediment) in the channel from bank and upland erosion;

(c) High coliform bacteria counts from upper watershed sources, which the author states may not have critical effects on fish;

(d) Channel widening from hoof-caused bank sloughing and later erosion by water;

(e) Change in the structure of the water column and the channel it flows in;

(f) Change, reduction, or elimination of vegetation;

(g) Actual elimination of riparian areas by channel degradation and lowering of the water table; and

(h) Gradual stream channel trenching or braiding depending on soils and substrate composition with concurrent replacement of riparian vegetation with more zeric plant species.

Skovlin states that vegetative conditions and response to grazing on meadows of the high plains and arid areas of the Basin and Range Province of the Intermountain West and Southwest should not be different from the response of a mountain meadow ecosystem. We disagree because land types, vegetation types, amount of rainfall, soil conditions, and length of growing season vary greatly among these areas. Recognition of these differences is a key factor in developing acceptable grazing management plans. Behnke and Raleigh (1979) listed three general dominant classes of riparian habitats--forested, willow-shrub, and herbaceous--that should be identified and managed in accordance with their different degrees of resistance to and recovery from overgrazing by livestock. Riparian areas need to be considered as separate habitat types from upland range areas in livestock grazing management plans (Behnke and Raleigh 1979, and Platts 1979).

We have found a basic difference in the approach of range, wildlife, and fishery scientists when evaluating livestock grazing. Range scientists tend to base their conclusions on the results of grazing management actions on vegetation recovery or meat production. Wildlife scientists base their conclusions on wildlife population size and the amount and condition of vegetation use by wildlife, especially on winter ranges. Fisheries scientists study the quantity and kinds of fishes present and the ability of the aquatic ecosystem to meet their habitat requirements.

It is no small wonder that managers have difficulty in agreeing on what constitutes successful and best available management practices because the discipline studies are not integrated. Managers are basing our management decisions on different sets of criteria. We did not find a single published comprehensive, interdisciplinary grazing study in our review. There is a compelling need for such studies to identify common goals and establish acceptable approaches to problem solving that will incorporate the concerns of all users, including ranchers, fishermen, hunters, ecologists, and recreationists.

Skovlin searched the literature for information on the effects of grazing on riparian habitats to reach an understanding of the adverse effects of grazing and beneficial effects of grazing management. This approach is commendable. The literature is overbalanced with studies on the effects of overgrazing, but is almost devoid of those management practices that are capable of mitigating or rehabilitating these effects.

The literature reviewed by Skovlin contends that today's range is much improved over conditions in the early 1900's. Busby (1978) states that range conditions today are far better than the denuded, deteriorated rangelands that existed in the early 1900's. We agree, but must point out that observations and studies leading to this interpretation are based mainly on vegetation responses on upland sites and usually do not take into account the condition of the riparian/stream habitat. Platts (in press [a]) believes the upland terrestrial range has recovered, but that riparian/stream areas have not improved measurably. Also, the majority of the literature has centered on response in cattle-grazed allotments and very little research on response in sheep-grazed allotments.

Skovlin omitted grazing by sheep as an alternative to correcting grazing problems but sheep grazing should be an option. Sheep have the potential of converting forage to red meat without extensively affecting certain riparian habitat classes, but they are no longer utilized on many allotments. Platts (in press [b]) has demonstrated that on a high elevation meadow allotment, sheep grazing under a herded rest-rotation system is compatible with good management of the riparian/stream system. In range management determinations, the best use of the allotment seldom considers what animals are best suited to graze the riparian areas it include We urge more consideration of this option in grazing management.

In planning for timber harvest, land is studied for its suitability for logging and for the feasibility of the transportation system necessary to move the logs. If an area of land is judged too unstable to log, it is excluded from logging. If certain types of logging and road construction practices are necessary for environmental protection, these are worked into the timber removal plan. In range management planning, the first step, similar to the procedures used in timber harvest, should be to determine the suitability of the habitat types for grazing. The second step on those lands classified for grazing should be to determine the class of livestock best suited for the area. The third step should be to determine the best grazing strategy and, finally, the last step should be to apply the grazing intensity that meets animal distribution patterns. This planning sequence can be more successfully implemented as better data banks become available.

The overall assessment of the livestock-fishery interaction studies reviewed by Skovlin is that the heavy grazing or overgrazi effects are the ones most often cited. Most habitat comparisons were based on fish responses to heavy grazing versus fish response to habitats excluded from any grazing. Studies using moderate or light stocking rates, the preferred rates used by rangeland managers, were less evident. Also, degraded areas were selected for study, but grazing intensities or vegetation use were seldom reported.

We proposed that there is some validity in using studies that relate to the effects of heavy grazing. For example, in Platts' study sites[3] scattered through Idaho, Utah, and Nevada, where livestock grazing intensites have been set by range managers to meet land management goals, the riparian areas are heavily grazed. The riparian zones averaged 70% herbage utilization, with one allotment using almost 100% of the available herbage in the riparian zone to obtain the preferred grazing rates on the upland sites. Unless the riparian zone also receives consideration, it will continue to be the "sacrifice area" in order to meet grazing management goals in the remainder of the allotment.

Skovlin goes on to say that findings in range and watershed management studies show that heavy levels of grazing during the growing season degrade the range environment, but that moderate and light levels of grazing have few irreversible effects on the range. We believe this may not be the case for moderate grazing in all riparian types, however, because the quality rating applied to the range environment is often in the eye of the beholder. Proper grazing management in riparian areas in the total ecosystem concept has never been defined to the satisfaction of all of the users. Many range specialists still define grazing intensity and utilization as they relate to vegetative conditions only, and then only in reference to the key forage species. Under this type of analysis, the brushy riparian environment could go by the wayside while the range environment would still be classified as improving, and perhaps as in good or excellent condition.

Skovlin states that there has been no common goal for researchers, who study riparian systems, and for range managers, who make grazing decisions that affect riparian conditions. We concur; to date there has been no prioritization of the best uses of the different classes of riparian/stream environments. Therefore it is difficult to determine grazing success in a total ecosystem concept. Each user visualizes effects from a different perspective. Under a multiple use concept, use of one resource should not be pursued to the exclusion of all others. Ironically, seldom can the land be managed to achieve optimal production for all competing uses.

Skovlin leads the reader to believe that specialized grazing systems with proper intensities are the answer. This may be true, but we find that these systems have yet to demonstrate that they will work on the various classes of riparian habitats. Rest-rotation grazing can greatly increase range forage production, but there is no acceptable evidence that it can improve a badly degraded riparian environment and its bordering fishery habitat. Our studies are beginning to indicate that rest-rotation grazing under commonly used intensities will not restore riparian/stream habitats.

---

[3] Platts, W. S. 1978. The effects of livestock grazing in high mountain meadows on aquatic environments, streamside environments, and fisheries--study plan. USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah. 100 pp.

Continuous grazing at reasonable intensities is not always bad. Deer and elk herds graze uncontrolled on our study sites, but the use of riparian vegetation is so low that the effects are insignificant. Continuous grazing with cattle, however, is not a viable alternative for grazing in most allotments with riparian zones because cattle prefer such areas. Grazing systems will not be successful until the reason for their design is known. The reason for failure of many systems is that their purpose did not correspond to the multiple use concept of management.

Myers (1981) compared streambank erosion, condition of woody plants, and animal droppings per hectare along 44 grazed streamside zones in Montana. Comparisons were made among willow-, birch-, dogwood-, and aspen-dominated riparian habitats. The riparian conditions of the 44 grazed streamside zones were compared with the riparian conditions of four ungrazed zones. Myers found that there was no correlation between riparian condition and the type of grazing system used. The grazing intensity was an important factor in resulting riparian condition, but not as important as amount of vegetation used during the hot season of the year. It was found that vegetation did not respond when defoliated during this period.

Skovlin concludes that conventional management strategies tailored to extensive range-grazing for livestock production and forage maintenance do not seem to achieve acceptable animal distribution in the highly preferred riparian zones. Therefore, range managers must search for specialized grazing systems that protect critical habitat reaches or some of these areas will be lost--at least temporarily--as a source of forage for livestock and wildlife.

Skovlin suggests that grazing can enhance environmental conditions for certain forms of wildlife. We believe that to state that current livestock grazing management strategies can enhance any but the most severely degraded salmonid fish habitats would be mainly conjecture. When European man first started to inhabit the western United States, the rivers and streams were teeming with game fish. No presently known grazing strategy, employing commonly used stocking and forage utilization levels, will restore a degraded stream to this point of environmental quality where livestock grazing intensity is the limiting factor. Fisheries and wildlife interests will have to accept something less than optimal production in most grazed riparian/stream ecosystems.

Skovlin also states that based on available literature, other specialized systems of grazing that rest, defer, or rotate in seasonal or annual succession would probably take 15 or more years for needed improvement in the riparian zone, unless aggressive conscientious distribution efforts were made. We agree with the 15 or more years, especially with the "more." Skovlin seems to consider riparian vegetation response as the key indicator of rehabilitation, but we must caution that the impacts on the fishery environment go far beyond just the improvement of riparian vegetation. A well-vegetated riparian zone is one of the keys to maintaining a healthy stream. But, once the stream is damaged, recovery depends upon a number of additional factors: channel and bank morphology, instream cover, and water flow regimens being chief among them. Therefore, for scientists, managers, and planners to predict the time required, or the strategies needed for rehabilitation, the total ecosystem needs to be evaluated. Skovlin hints at this problem when he states that we have little or no information for predicting the appearance of the successional stages in the riparian zone, or when ideal or even acceptable conditions might be reached with full protection from grazing. This is especially true if he is referring to total riparian/stream rehabilitation and not just revegetation.

We stress that rangeland streams in the West are in their present condition because many small, annual, degrading effects were cumulative over time, and after 100 years they constitute major changes in the fishery. Today's land managers not only must administer their grazing strategies with finesse to meet today's needs, but they must also correct the mistakes of the past.

Skovlin suggests after studying 23 reports, that once proper grazing has been established, fish biomass can double in a matter of 3 to 5 years. The reader should be cautious about accepting this statement as fact; Skovlin has acknowledged that some of these studies are not experimentally sound nor statistically reliable. Some studies, however, have shown rapid recovery of stream habitat sections and fish populations after cattle grazing was discontinued (Raleigh and Duff in press). We point out that other studies have shown much slower recovery for riparian/stream habitat (Platts in press [b]).

Based on our studies, it appears that stream recovery from changes in overgrazing often is a slow rebuilding process. Only under special circumstances of low fish occurrence, excellent streamflow regimens, and rapid vegetation responses would you find a stream that would double its fish population in 3 to 5 years because of sudden improvements in grazing management. When more data have been accumulated that will allow this type of analysis for different climatic zones and riparian classes, we predict that on many riparian/stream ecosystems it will be statistically impossible to determine significant changes in fish populations in 3 to 5 years. The rehabilitation of many of our western streams will be a slow process.

Skovlin states that the importance of bank stability to fisheries habitat centers on the reduction of silt (sediment) production. We agree, this is important. Of equal or more importance, however, is the loss of good channel and bank morphology resulting from continued streambank instability. Skovlin also states that the retarding effect of long-term browsing on riparian shrub regeneration has a greater net effect on bank stability and resulting sediment than does bank cutting from the mechanical action of hoof treading. The key term here is long-term; we doubt that many studies are sufficiently long-termed enough to test this statement. Ongoing studies by Platts (1978) indicate that the reverse may be true. The high percentage of western set-back streambanks with shrub-dominated riparian vegetation also attests to the fact that hoof treading is an important factor.

Skovlin states that grazing systems that postpone use of riparian zones until late season, until restoration is acceptable, provide a good measure of protection without heavy expense. This assumes that late season grazing results in cattle leaving the riparian areas for the uplands. This reasoning should be carefully interpreted as the cattle may not leave.

On one of our current study sites in a long glaciated U-shaped valley in Idaho, a late grazing system would help restore riparian quality because cattle move to the uplands in late summer and fall when the cold air pocket forms over the bottomlands. At another study site 15 miles away in a flat broad valley, however, cattle are drawn to the riparian areas during late season because they contain the only remaining succulent vegetation. Seasonal grazing, proper intensity, and cattle distribution will achieve improvements in riparian/stream habitats, but the system must be matched to the physical conditions of the grazing area.

MANAGEMENT ALTERNATIVES

Skovlin states that land managers must know what courses of action (solutions) are available before allocating or partitioning riparian zone resources in rangeland settings. This has been true throughout the past century; and we point out that the reason for the past degradation of riparian environments is because acceptable courses of action were not sought or were not available in many cases and are still not available. We look for research to provide these answers in the next few years that will allow managers to greatly improve range management.

Skovlin reports that the literature shows that specialized grazing systems can bring back degraded riparian habitats, but he does not identify what these systems are. Specialized grazing systems under study today can upgrade riparian habitats, but only if they are matched closely with required intensity. Skovlin believes that exclusion of the riparian zone by corridor fencing provides optimum protection in the shortest possible time. He suggests that perhaps 75% of the potential benefits to the aquatic habitat occur in the first 5 years. This may be true in certain selected habitats, but our rehabilitation studies do not support these findings. Some improvements are occurring in the riparian vegetation, but not in the aquatic system. We would estimate that we have received less than 15% of our potential benefits at this time. It took many years under improper grazing for most aquatic systems to reach their present degraded state, and it would be erroneous to predict immediate short-term rehabilitation benefits based on today's knowledge of riparian rehabilitation.

Based on reports of biological response, Skovlin found the impacts of light or moderate grazing to be half or less that of heavy grazing. Therefore, he predicts that it would take twice the recovery time for response under heavy grazing as under light or moderate grazing. To evaluate this conclusion, one must consider the discussion we presented previously on proper grazing. The end point from impacts caused by moderate or heavy grazing in certain riparian-aquatic habitats can be the same. More research is needed to fully respond to this conclusion.

Skovlin lists 10 options for land managers to consider in making their grazing management decisions. We fully agree with these options, but would like to add three more:

1.--The option of classifying the land as to its capability for grazing;

2.--The option of determining the best kind and class of livestock to graze the allotment or segments of the allotment; and

3.--The option of decreasing utilization for short periods of time if nothing else will bring needed improvement.

We agree with the author's conclusions that critical stream reaches must be identified and target levels established for achieving acceptable habitats over a specific period of time. Drawing from the literature (Interagency Wildlife Committee 1979), Skovlin suggests that some conditions for optimum fish habitat are:

1. Sixty percent or more of the stream should be shaded between 10 a.m. and 4 p.m. during summer months.

   Our comment: This may be true in some habitat types but it is an impossibility in many others. In our high elevation meadows that successfully rear salmon and steelhead, this much shade may be undesirable.

2. Eighty percent or more of the streambank should be in stable condition.

   Our comment: In some streams with tender banks, 20% of the streambank in an unstable condition could cause the complete stream channel to unravel causing heavy sediment loads.

3. Not more than 15% of the stream bottom should be covered by inorganic sediment.

   Our comment: Stream channels are composed of inorganic sediments. If this refers to fine sediment then 15% over salmon-steelhead trout spawning areas is probably too high. Fifteen percent fine sediment 0.03 inch (<0.8 mm) in redds can cause almost complete mortality of the young.

The point we are making here is the state-of-the-art is not well developed enough for establishing target levels except for broad general planning.

TERRESTRIAL WILDLIFE

Skovlin states that the impact of grazing on birds is variable, depending on where a bird species feeds or nests, and when grazing takes place. A few birds such as the killdeer (Charadrius vociferous) may actually benefit from grazing. Grazing probably benefits the killdeer by creating open spaces devoid of vegetation. Nest structures on open ground, unprotected from livestock trampling may be more critical in survival, however, than loss of food supply or creation of open space. Loss of vegetation in the spring also leads to higher predation on eggs and ground-nesting birds.

We agree with Skovlin that cover removed by grazing may alter feeding and nesting habitats. If planned (grazing strategies), the direct effects of grazing can be beneficial for birds of prey and for ground feeders. We agree that the breeding habitat of sage grouse (Centrocercus urophasianus Bonaparte) may be improved, but in sage grouse management it must be remembered that good breeding habitat is very limited; strutting grounds are generally traditional. Loss of cover in the adjacent nesting areas makes these strutting grounds ineffective.

Skovlin states that of the common large herbivores which inhabit riparian zones and associated mountain meadows, elk (Cervis canadensis) are perhaps best known for their preference of these areas. Marcum (1975) has demonstrated that elk show heavy preference for summer range near permanent water sources. Some elk calve in riparian areas, therefore, disturbance during these critical periods can lead to elk seeking marginal sites; higher calf mortality results.

Elk use our Idaho study sites, which are all on mountain meadows, primarily for calving and for spring to early summer feeding. Most of their time, however, is spent around the meadow fringes close to conifer escape cover, and we have been unable to detect significant use in the streamside areas. In many cases in Idaho, the willow cover along riparian areas becomes important as a winter feed for elk and moose (Alces americana) because snow depths preclude use of shorter vegetation. Possibly because of the frozen banks and deep snow cover, however, effects on streambanks appear to be insignificant.

Skovlin states that the effects of large wild ungulate browsing in riparian zones is normally not great in fall and winter, but is heavy during spring and early summer before livestock grazing begins. During this period, wild ungulate impacts can be significant in terms of shrub survival during the ensuing growing season. This leaves the reader with the idea that wild ungulates are guilty of a major impact on shrub survival prior to use by livestock. The question is, are we talking of only livestock ranges or wild ungulate ranges? Certainly, there must be some prior rights for wildlife.

Skovlin attributes heavy, but unquantified, impacts from large wild ungulates to compaction of saturated or wet soils of upland range during early spring migrations in the Pacific Northwest. In Idaho (personal communication with Idaho Fish and Game Department and BLM big-game biologists), there is no known significant compaction of soils caused by migratory elk herds. In the fall and early winter, elk do migrate in large numbers, but in the spring, they usually move singly or in scattered groups of twos and threes. The compaction problem may have be related to elk herds moving into the National Parks from Wyoming and Montana. Idaho, one of the largest elk-producing States, evidently does not consider compaction to be a significant problem, however.

SUMMARY

Livestock grazing management on public lands is an issue of major concern to the public. Skovlin's report identifies this concern, evaluates the management, and offers some guidance for better range management. The author points out that there is abundant information available on the effects of livestock grazing on plant communities, livestock production, and watershed response (not including streams), but little on riparian habitat response. To date, there are few studies that tell the reader how any present cattle grazing strategy will adequately restore riparian-stream habitats in a reasonable time frame.

We believe the solution is to find grazing strategies that will protect and restore riparian-stream habitats, but this aim is being blocked by the approach taken to problem solving. Range conservationists, wildlife scientists, fisheries scientists, and watershed scientists look at problems and solutions from their own bias; so decisionmakers are not making management decisions aimed at a common goal. Even the term "proper grazing" has yet to be defined in an ecological frame that can be used by all disciplines.

Thus, the contention by some managers and scientists that range conditions have improved dramatically since the early 1900's does not always meet with agreement. Because range scientists are looking at the uplands and fisheries biologists are looking at riparian areas, they can arrive at two different answers to the same question. For successful range management, all disciplines should work together to identify the best approaches to the four steps we outlined for making range management decisions. Those steps are: (1) determine the suitability of the habitat types for grazing; (2) determine the best kind or class of animal to do the grazing; (3) construct the optimum grazing strategy; and (4) to apply the correct grazing intensity matched with the needed distribution.

To make this sequence work, land managers must know what alternatives are available before allocating or partitioning a riparian zone for resource use. Correct specialized grazing systems can protect and enhance riparian habitats, but these have not been identified. Identifying such grazing systems should be the major thrust of range research over the next decade. It took many years under improper grazing for most aquatic systems to reach their present state. It would be a mistake to think all streams are going to improve in the near future under presently used grazing strategies and intensities. Needed are some major breakthroughs in both research and management understanding of how riparian-stream habitats react to stress and to the release of stress. We must know how to minimize stress before we can fully protect and enhance our riparian-stream habitats.

REFERENCES CITED

Behnke, R. J., and R. F. Raleigh. 1979. Grazing and the riparian zone: impacts and management perspectives. Proc. Symposium on Strategies for Protection and Management of Floodplains, Wetlands, and Other Riparian Ecosystems, Atlanta, Georgia.

Busby, F. E. 1978. Riparian and stream ecosystems, livestock grazing, and multiple use management. Grazing and Riparian/Stream Ecosystems Forum Proc., Trout Unlimited, pp. 6-12, Vienna, Virginia.

Interagency Wildlife Committee. 1979. Managing riparian ecosystems (zones) for fish and wildlife in eastern Oregon and eastern Washington. Riparian Habitat Subcommittee of the Oregon/Washington Interagency Wildlife Committee, March 1979, 44 pp.

Marcum, C. L. 1975. Summer-fall habitat selection and use by a western Montana elk herd. Ph. D. Thesis, University of Montana, Missoula, 188 pp.

Myers, L. 1981. Grazing management versus riparian management in Southwestern Montana. Abstract for Proc. of the 34th Annual Meeting of the Range Society, Tulsa, Oklahoma.

Platts, W. S. (In press a.) Overview on the riparian/fish habitat issue in the Western United States. Western Proc. 60th Annual Conference of the Western Association of State Game and Fish Commissioners, Kalispell, Montana.

Platts, W. S. (In press b.) Sheep and cattle grazing strategies on riparian-stream environments. Wildlife-Livestock Relationships Symposium, Couer d'Alene, Idaho, University of Idaho, Moscow, Idaho.

Platts, W. S. 1979. Livestock grazing and riparian/stream ecosystems-an overview. Proc. Forum-Grazing and Riparian/Stream Ecosystems, Denver, Colorado, November 1978, pp. 39-45, Trout Unlimited, Vienna, Virginia.

Raleigh, R. F., and D. A. Duff. (In press.) Trout stream habitat improvement: Ecology and hydrology. Wild Trout Symposium II, Yellowstone National Park, Trout Unlimited, Vienna, Virginia.

Thomas, J. W., C. Maser, and J. E. Rodick. 1979. Riparian zones in managed rangelands-their importance. Proc. Forum-Grazing and Riparian/Stream Ecosystems, Denver, Colorado, November 1978, pp. 21-30, Trout Unlimited, Vienna, Virginia.

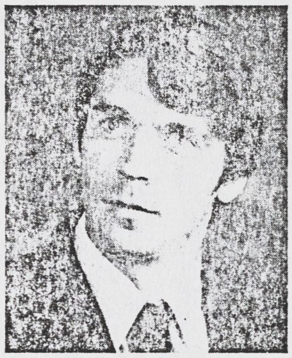
U.S. Department of the Interior, Bureau of Land Management. 1976. Final environmental statement, proposed domestic livestock grazing program for the Challis planning unit. Appendix 2-G, Economic Analysis of Chinook Salmon Produced in the Challis Planning Unit, pp. A-32-A-34.

FISHERIES MANAGEMENT AND FISH DEPENDENT BIRDS

Michael Dombeck, James Hammill, and William Bullen

ABSTRACT

Management of aquatic ecosystems can affect sensitive piscivores such as bald eagles, ospreys, and loons. Fisheries biologists must be aware of the needs of these species and should prepare multiple-use management plans jointly with wildlife biologists where these avian species occur. The needs of these birds should be included in fisheries management objectives, and human disturbances should be minimized. Proper fish population manipulation and habitat management can enhance the feeding opportunities of these and other fish-dependent birds.



Michael Dombeck

James Hammill

Fisheries management can affect bald eagles (*Haliaeetus leucocephalus*), ospreys (*Pandion haliaetus*), common loons (*Gavia immer*), and other avian piscivores in both positive and negative ways. These species and others are, at least in part, dependent upon a fish diet for survival. Few agencies have guidelines for managing waters where these species occur. The Endangered Species Act of 1973 directs federal agencies to carry out programs for the conservation of endangered and threatened species. More than half of the states have adopted similar legislation. Other sensitive species also require special consideration. In addition, interdisciplinary land management planning is mandated by law or directed by policy on many federal and state lands.

THE AUTHORS: **Michael Dombeck** is a fisheries biologist with the USDA Forest Service, Chequamegon National Forest. He received his B.S. in biology from the University of Wisconsin in 1971, an M.S. in zoology from the University of Minnesota in 1977, and is currently a Ph.D. candidate in fishery biology at Iowa State University. **James Hammill** is a wildlife biologist with the Michigan Department of Natural Resources. He received his B.S. in biology from Adrian College in 1971 and did graduate work at Michigan State University in wildlife biology. **William Bullen** is a district fisheries biologist for the Michigan Department of Natural Resources and is responsible for fisheries management in the central portion of Upper Peninsula. He received his B.S. in fisheries and wildlife from Michigan State University in 1965.

As resource management plans are developed, conflicts often arise in the determination of management schemes for waters utilized by eagles, ospreys, and loons. These conflicts result from differences in the specialized opinions of professional fisheries and wildlife biologists, as well as differences in public values. The resolution of these conflicts requires the highest level of professional cooperation between fisheries and wildlife biologists. The end result must be a management program which is responsive to the law, to the needs of the public, and to the professional expertise in both fish and wildlife disciplines. Continued controversy and litigation will be the price of our failure to resolve these conflicts.

This paper is not intended to be a comprehensive treatise of the topic, but rather a "springboard" for thought for inland fisheries biologists. Suggested guidelines are based on the literature, consensus of expert opinion, fragments of data, and various guidelines in agency files.

The objectives of this paper are: (1) to urge fisheries managers to avoid the single discipline approach to aquatic resource management when fish-dependent birds are present; and (2) to suggest guidelines for aquatic management objectives and activities when piscivorous birds are present.

Bald eagle management guidelines usually state that waters utilized by eagles should be managed to sustain them. Guidelines for the management of waters for ospreys and loons are generally similar. These species are highly visible indicators of wilderness and relatively pristine landscapes. They are also resources highly valued by the public. Thus, the fisheries manager is responsible for the management of waters to provide food, nesting habitat, and seclusion for these fish-dependent birds, yet little if any specific information is provided to the fisheries manager concerning the needs of the birds. Direction regarding fisheries management schemes that benefit piscivorous birds is sparse.

FISHES UTILIZED BY EAGLES, OSPREYS, AND LOONS

The bald eagle is basically a carrion feeder on freshly dead or dying fishes or terrestrial animals. Several studies document that inland bald eagle populations rely heavily on fishes. In Maine, Todd et al. (1982) found that fish comprised 77% of food debris accumulated at eagle nests. They found that brown bullheads (*Ictalurus nebulosus*), white suckers (*Catostomus*

[Mar-Apr] 1984

Limnol. Oceanogr., 30(3), 1985, 565–576

Diel migrations of a zooplanktivorous fish (*Menidia beryllina*) in relation to the distribution of its prey in a large eutrophic lake[1]

Wayne Wurtsbaugh[2] *and Hiram Li*[3]
Department of Wildlife and Fisheries, University of California, Davis 95616

Abstract

Diel changes in the distribution of the tidewater silverside (*Menidia beryllina*) and its prey were measured in Clear Lake, California, a large, shallow, eutrophic lake. Zooplankton prey densities were low in the littoral zone, but increased rapidly to near peak abundances 50–200 m from shore. Gill netting, trawling, and visual observations showed that tidewater silversides migrated both horizontally and vertically to feed in areas of high zooplankton abundance. At night the fish concentrated near shore and did not feed. At dawn (8×10^8–2×10^{10} photons cm^{-2} nm^{-1} s^{-1}) the fish migrated lakeward at least 50–1,000 m, and littoral abundance decreased from more than 100 m^{-2} to only 0.1 m^{-2}. The migration preceded the initiation of feeding by 30–60 min. After feeding 2–4 h, the fish returned to the littoral zone and swam rapidly (6–11 body lengths s^{-1}) parallel to shore in narrow, continuous schools until resting aggregations formed. The fish returned to shore before they were satiated, perhaps to balance predation losses in offshore areas against foraging gains. A second period of offshore activity and feeding occurred in the afternoon and evening.

The behaviors of predators and prey that affect spatial-temporal overlap are important in regulating predation in aquatic systems (Stein 1979; Mittelbach 1981). The overlap in distribution that makes predation possible may be dynamic: seasonal and diel changes in distribution can be important regulators of predation. For example, diel changes in the spatial-temporal distributions and predation of fish are important in structuring marine reef fish communities (Hobson 1972). Similarly, the diel vertical migrations of zooplankton are an important behavioral mechanism regulating fish predation on plankton (Begg 1976; Zaret and Suffern 1976; Wright et al. 1980).

Horizontal distribution patterns of fish and zooplankton also affect predation processes. Fish are not evenly distributed horizontally in lakes, but the distribution patterns of only a few species are known (Hall and Werner 1977; Keast 1978), particularly with respect to diel changes (Emery 1973; Hall et al. 1979; Hanych et al. 1983). Similarly, the horizontal distributions of zooplankton are poorly understood; the distributions can be patchy (Cassie 1961), some zooplankters avoid the littoral zone (Siebeck 1980), and concentrations or voids of plankton can occur near the shores of lakes (George and Edwards 1976). There have been few attempts to determine the interaction between the movements of zooplanktivorous fish and their heterogeneously distributed prey.

Diel inshore-offshore migrations of freshwater fish have been recognized for many years (Cahn 1927; Hasler and Bardach 1949; Moyle 1973). These diel migrations may be important for behavioral thermoregulation (Caulton 1978), spawning (Middaugh et al. 1981), predator avoidance (McFarland et al. 1979; Hanych et al. 1983), and feeding (Baumann and Kitchell 1974; Hall et al. 1979; Bohl 1980).

We studied the diel horizontal and vertical migrations and behavior of a small atherinid fish, the tidewater silverside, *Menidia beryllina,* in Clear Lake, a large eutrophic lake in northern California. We describe here the timing of these migrations in relation to the distribution of the zooplankton prey and light intensity and discuss the hypotheses that the migration pattern is related to feeding, behavioral thermoregulation, spawning, and predator avoidance.

---

[1] This work was financially supported by the National Science Foundation (DEB 74-23702), a University of California Jasto Shields Scholarship, and the Lake County Mosquito Abatement District.

[2] Present address: Department of Fisheries and Wildlife (UMC 52), Utah State University, Logan 84322.

[3] Present address: Oregon Cooperative Fishery Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis 97331.

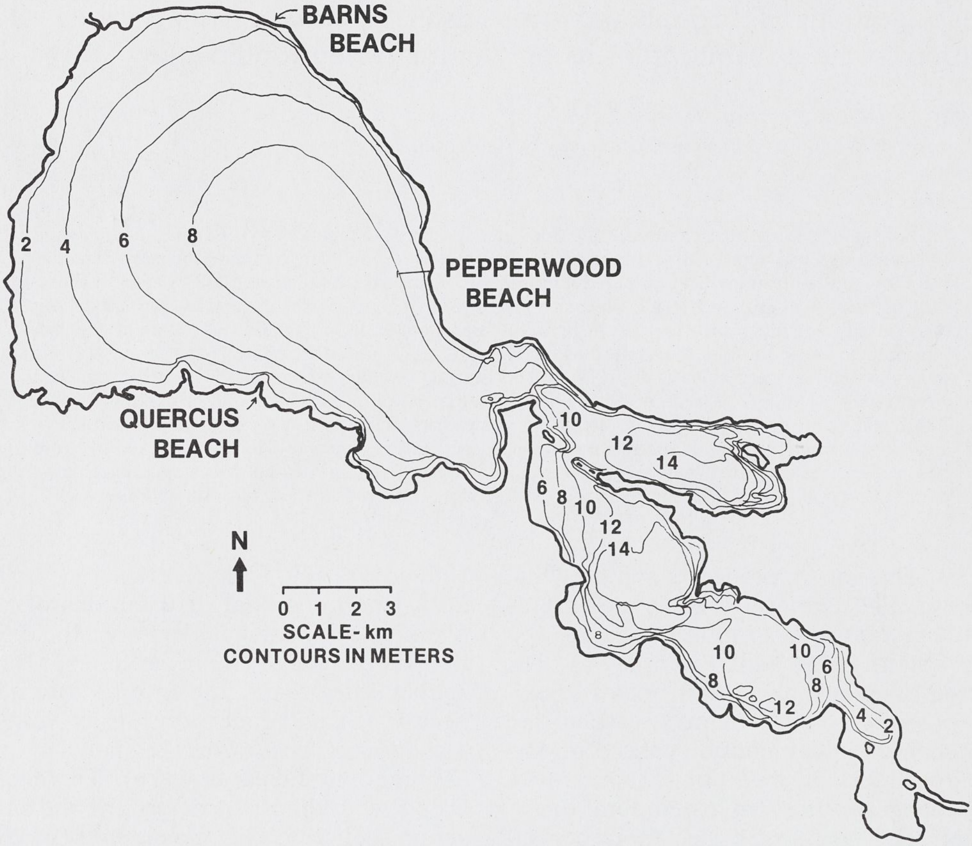


Fig. 1. Morphometry of Clear Lake, California, showing the principal study sites, including the transect line used for fish and zooplankton sampling at Pepperwood Beach.

We thank P. Moyle and A. Colwell for participating in many aspects of the study and reviewing the manuscript. Others who assisted include: N. Anderson, R. Axler, D. Baltz, T. Coon, B. Daniels, L. Decker, J. Dentler, D. Griffy, S. Jacobs, L. L'Ai, M. Leclaire, J. Li, A. Linden, D. Longanecker, D. Loshbaugh, M. Morgan, N. Nealey, L. Tharldsen, S. Tjornehoj, and B. Vondracek. A. Horne, D. Woodward, N. Anderson, R. Drenner, and D. Hall provided review comments.

Materials and methods

Study area—Clear Lake is a large (170 km^2), shallow (mean depth 8.1 m), polymictic lake located in the coast range of northern California (39°N, 121°W) at an elevation of 404 m. This study was done in the upper basin of the lake, which has an area of 127 km^2 (Fig. 1). Mean water temperatures range from 6°–8°C in winter to 25°–27°C in summer and there is usually <3°C difference between surface and bottom. The lake is productive, having frequent, dense blooms of blue-green algae (Horne and Goldman 1972). Algae and inorganic turbidity limit light penetration, and Secchi disk depths normally vary from 0.2 to 4.0 m ($\bar{x} = 1.2$ m). The bottom of the upper basin is largely flocculent mud and the shoreline consists primarily of sand and gravel beaches or dense stands of rushes (*Scirpus* spp.). There is little submerged aquatic vegetation because light penetration is limited and because the lake level is regulated by a dam at the outflow and fluctuates about 2 m annually.

Behnke
FYI

COEXTRUSION OF CARP (CYPRINUS CARPIO) AND RICE FLOUR

JOSEPH A. MAGA[1] and THOTA REDDY[2]

Colorado State University
[1]Dept. Food Science and Human Nutrition
[2]Dept. Fishery and Wildlife Biology Fort Collins, CO 80523

Accepted for Publication May 7, 1985

ABSTRACT

Rice flour and varying amounts (10-35%) of deboned minced carp were coextruded resulting in a precooked blend that developed no detectable off-odors after being stored at room temperature for up to six months. In addition, the extrudates, along with nonextruded rice flour, were made into pakodas, a fried Indian snack food. Sensory triangle test data showed that up to 25% carp could be added before a statistical difference was noted. Hedonic sensory data demonstrated that consumer acceptable products relative to pakodas appearance, aroma, flavor, texture and overall acceptability can be made even at carp addition levels of up to 35%.

INTRODUCTION

Fish represents a food of good nutritional quality but because of its extreme perishability, a large portion of the world fish catch is lost. Therefore, fish preservation is an area of major concern. A major advantage of thermal food extrusion is that a room temperature shelf stable precooked product can be produced.

From a nutritional standpoint, the practice of blending foods is encouraged. Examples include the blending of various cereals and legumes.

In many parts of the world, carp *(Cyprinus carpio)* is a highly desirable species, and in these same areas, rice is usually the major cereal crop. The protein content of rice is relatively low (6-9%) while that of carp is significantly higher. To date, the authors are aware of only one investigation where fish has been coextruded (Murray *et al.* 1980). Defatted soy flour and minced Atlantic cod were successfully coextruded, but a Canadian taste panel found the resulting product to have an objectionable fishy flavor.

Therefore, the primary objective of this study was to evaluate the influence of extruded carp and rice flour ratios on the consumer acceptability of a popular Indian rice flour-based snack food (pakodas).

Journal of Food Processing and Preservation 9 (1985) 121-128. All Rights Reserved.

MATERIALS AND METHODS

Ingredients

Commercial white rice flour was obtained (Comet Rice Mills, Inc., Houston, Texas).

Local lake carp averaging 3 kg each were netted and held live in fresh running water for 10 days to reduce muddy odor and taste. They were filleted, resulting in yields of 25-30% based on whole fish weight. The flesh was mechanically ground through a 0.63 cm hole plate using a household meat grinder. The minced flesh was combined and frozen at -36°C in 1 kg packages until used.

Proximate Analysis

Moisture, fat and protein were determined for the rice flour and minced carp (AOAC). A protein conversion factor of 5.95 was used for rice and 6.25 for fish. The same analyses were performed on the extrudates as well as for prepared pakodas with proportional protein conversion factors utilized.

Extrusion Formulations

Based on initial rice flour and carp moisture contents, a series of samples containing from no carp (control) to 10, 15 and 20% minced carp was made. The moisture content of the mixtures was adjusted to a total of 25% since preliminary extrusion runs indicated that products having moisture contents in excess of 30% were difficult to process. Potential protein denaturation was not considered. To increase the proportion of fish above 20%, the moisture content of the minced fish was reduced to 50% by baking 1 kg units at 120°C for 40 min. Using this cooked product, additions of 25, 30 and 35% carp to rice flour were made. Two kilogram flour/fish/water mixtures were blended in a 20 liter Model B20T Blackslee vertical mixer equipped with a wire ship. Mixing was for 5 min at speed 1, and 15 min at speed 2. A summary of all formulations used for extrusion are presented in Table 1.

Extrusion

A Model PL-V500 Brabender Plasticorder extruder equipped with a 3/1 screw and a 0.5 cm die was used. The unit was operated at 150 RPM with a barrel temperature of 150°C. Each of the seven formulations shown in Table 1 was extruded on three consecutive days in a sequential fashion for a total of 21 runs.

Table 1. Extrusion formulations*

Variable	% Rice Flour	% Carp/Form	% Added Water
1	100	0/raw	14
2	90	10/raw	7
3	85	15/raw	3
4	80	20/raw	0
5	75	25/cooked	4
6	70	30/cooked	2
7	65	35/cooked	0

* All formulations had calculated total moisture contents of 25% prior to extrusion.

Extrudate Drying, Grinding and Storage

The extrudates were collected and permitted to air dry for 24 h. Samples were ground in a Model 4 Wiley laboratory mill through a 1 mm opening screen. Representative samples of the ground products were placed in Mason jars, sealed, and stored at either -36°C or 22°C for up to six months for flavor evaluation. A sample of nonextruded rice flour was also subjected to these same storage conditions.

Pakodas Formulation

A standard recipe for pakodas, as shown in Table 2, was used. The ingredients were blended into a batter, 10 g units added to 210°C cooking oil, and fried for 2.5 min. The snacks were removed from the oil, drained on paper towels for one minute, and presented to the panel. The seven extruded products shown in Table 1, along with a nonextruded rice flour control, were formulated in pakodas.

Sensory Panel Makeup and Evaluation

A group of 22 Indian students and/or spouses familiar with pakodas attending Colorado State University was used as the panel. They included 15 males and 7 females, and ranged in age from 20 to 46.

Table 2. Pakodas recipe

100 g rice flour or ground extrudate
100 g water
2 g salt
0.5 g ground black pepper
40 g finely chopped onions
10 g finely chopped green Bell pepper

The same group was used to evaluate the odor properties of the eight samples placed in storage. Ground samples were presented at 0, 3, and 6 months of storage and the panel asked to describe any objectionable odors.

Freshly prepared pakodas were evaluated by the panel using standard procedures for the triangle test (Amerine *et al.* 1965). In addition, separate samples of each variable, including the nonextruded and extruded 100% rice flour controls, were evaluated for their appearance, aroma flavor, texture, and overall acceptability using standard procedures for a seven point hedonic scale (Amerine *et al.* 1965). Data were statistically evaluated using standard tables associated with each of these sensory tests (Amerine *et al.* 1965).

RESULTS AND DISCUSSION

Proximate Composition

As seen in Table 3, the rice flour used had an initial moisture content of 11.0% and a protein content of 6.9%, whereas raw carp had 81.0% moisture and 18.2% protein. Cooking carp decreased moisture, thereby, increasing protein and fat amounts. Both rice flour and carp were relatively low in fat.

All of the ground extrudates had a moisture content ranging from 7.0 to 7.5%, which would lead to good storage properties. Using the protein content of extruded rice flour as the base, it can be seen that even the incorporation of only 10% raw minced carp increased the amount of protein by 17%, and when 35% cooked minced carp was added, protein content increased 86%. Thus, these extrudates represent a source of precooked food of relatively high protein content that could be consumed as such or be incorporated into other foods. Even at the highest carp addition, the fat content was still only 2.32%.

Table 3. Proximate composition of ingredients, extrudates and Pakodas*

	%		
Product	Moisture	Protein	Fat
Ingredients:			
Rice flour (RF)	11.0	6.9	0.42
Raw minced carp (RMC)	81.0	18.2	4.31
Cooked minced carp (CMC)	50.0	23.7	5.09
Extrudates:			
100% RF	7.4^a	8.3^a	0.47^a
90% RF/10% RMC	7.2^a	9.7^a	0.92^a
85% RF/15% RMC	7.4^a	10.3^b	1.14^b
80% RF/20% RMC	7.5^a	10.9^b	1.44^b
75% RF/25% CMC	7.3^a	13.3^c	1.80^c
70% RF/30% CMC	7.0^a	14.3^c	2.06^c
65% RF/35% CMC	7.1^a	15.4^d	2.32^c
Pakodas:			
100% non-extruded RF	12.6^a	6.4^a	7.42^a
100% extruded RF	12.2^a	6.5^a	7.17^a
90% RF/10% RMC	12.5^a	9.5^b	7.15^a
85% RF/15% RMC	12.9^a	10.0^b	7.15^a
80% RF/20% RMC	13.1^a	10.4^b	7.11^a
75% RF/25% CMC	14.6^b	12.8^c	7.03^a
70% RF/30% CMC	15.2^c	13.7^c	7.00^a
65% RF/35% CMC	16.0^c	14.6^d	7.00^a

* All data represent the average of duplicate samples run on each of three separate products. Column data within the extrudates and Pakodas listings with different letters are significantly different (p = .05)

In looking at the pakodas composition, it can be seen that the frying process resulted in the absorption of some oil since fat contents for all products was in the neighborhood of 7%, which is still relatively low for a fried food. Factors such as frying temperature, time, and pakodas size would influence the amount of fat absorbed. Also, it can be seen that the extrusion process did not influence composition of the two 100% rice flour controls. It also appears that increasing the carp content influenced water retention, since the final moisture content of the pakodas increased with increasing carp addition and, as would be expected, protein content also increased. Using the 100% rice flour pakodas as controls, the addition of 10% carp resulted in a 48% increase in protein, while the highest carp addition (35%) resulted in pakodas containing 128% more protein than the traditional 100% rice product.

Extrudate Storage Stability

The odor properties of the seven extrudates shown in Table 3, along with those of the nonextruded rice flour control, were evaluated at 0, 3 and 6 months of storage at -36° and 22°C. The 16 samples were randomly presented in powdered form at room temperature to the 22 member sensory panel who were asked to describe any objectionable odor. Even after 6 months, no objectionable odor were reported in any of the samples. Thus, it appears that the extrusion process is well suited to the manufacture of a product that has good odor storage stability. Factors that accounted for good stability include the relatively low moisture and fat contents of the extrudates. In addition, no strong fishy odor, as was found by Murray *et al.* (1980), was apparent in this study, thereby, demonstrating that starting fish quality is of major importance. Possible explanations for this difference include differences in fish species used and extrusion conditions. The higher the extrusion temperature, the greater the potential to flash off volatile odors.

Sensory Triangle Tests

It should be remembered that the triangle test is soley a difference test and not a preference test. Freshly prepared pakodas were submitted to the 22 member Indian panel on three consecutive days with each day representing separate extrusion runs. These results are summarized in Table 4. As can be seen, the panel could not distinguish between pakodas made from traditional rice flour and extruded rice flour. When pakodas made from extruded rice flour and increasing amounts of carp were compared, the panel could not statistically distinguish between 10, 15, 20 and 25%

Table 4. Pakodas sensory triangle test results*

Comparisons	Number of Correct Responses**
100% non-extruded RF vs. 100% extruded RF	6
100% extruded RF vs. 90% RF/10% RMC	7
100% extruded RF vs. 85% RF/15% RMC	7
100% extruded RF vs. 80% RF/20% RMC	8
100% extruded RF vs. 75% RF/25% CMC	10
100% extruded RF vs. 70% RF/30% CMC	14
100% extruded RF vs. 65% RF/35% CMC	17

* Results are the average of three separate evaluations
** 12 correct responses required at p = .05

added carp. However, at carp levels of 30 and 35%, the panel could statistically make distinctions. Therefore, it can be concluded that at least 25% carp can be added to pakodas before major differences become apparent. In referring back to Table 3, it can be seen that pakodas made with 25% added carp have a protein content of 12.8%, which is 100% higher than in the 100% rice controls. The intensity and amount of spices and frying conditions can be significant factors in dictating the maximum amount of carp that can be added before detection is obvious.

Sensory Hedonic Tests

The hedonic test is a classical preference test and, as seen in Table 5, no sensory property of any product variable was judged to be disliked. Relative to pakodas appearance, no significant difference was apparent until at least 25% carp was added. However, products containing 35% carp were still rated as looking moderately good. The golden brown color that develops during frying appeared to minimize color differences. The aroma ratings were statistically comparable for pakodas containing up to 20% carp, while with flavor, significant differences were found at levels exceeding 15% addition. It is also interesting to note, with flavor, that both the 100% extruded rice flour control and the product containing 10% carp were statistically better than the 100% nonextruded rice flour control. Texture was the sensory attribute that was judged the lowest, even for the controls. However, the texture of pakodas containing 35% carp was still not objectionable. When the data for overall acceptability are considered, again all

Table 5. Pakodas sensory hedonic test results*

Product	Appearance	Aroma	Flavor	Texture	Overall Acceptability
100% non-extruded RF	6.4^a	6.0^a	6.2^b	5.7^a	6.3^a
100% extruded RF	6.5^a	6.0^a	6.6^a	5.6^a	6.5^a
90% RF/10% RMC	6.4^a	6.2^a	6.6^a	5.6^a	6.5^a
85% RF/15% RMC	6.0^a	6.0^a	6.2^b	5.3^b	6.0^a
80% RF/20% RMC	6.0^a	5.7^b	6.3^b	5.2^b	5.5^b
75% RF/25% CMC	5.8^b	5.5^b	6.0^b	5.0^b	5.0^b
70% RF/30% CMC	5.4^c	4.6^c	5.7^c	4.5^c	4.5^c
65% RF/35% CMC	5.1^c	4.6^c	5.5^c	4.2^c	4.3^c

*Results are the average of three separate evaluations. Scale used:
7. Like extremely; 6. Like very much; 5. Like moderately; 4. Neither like nor dislike; 3. Dislike moderately; 2. Dislike very much; 1. Dislike extremely;
Column data with different letters are significantly different ($p = .05$)

variables produced acceptable results but significant differences were apparent after 15% carp addition. Thus, the above data demonstrate that a extruded rice-based snack food containing up to 35% carp is acceptable to a native Indian population.

REFERENCES

AMERINE, M. A., PANGBORN, R. M. and ROESSLER, E. B. 1965. *Principles of Sensory Evaluation of Food.* Academic Press, New York.

AOAC Official Methods of Analysis. 1975. Washington, D.C.

MURRAY, B. P., STANLEY, D. W. and GILL, T. A. 1980. Improved utilization of fish protein — co-extrusion of mechanically deboned salted minced fish. Can. Inst. Food Sci. Technol. J. *13,* 125-130.

[1985]

The Effects of Large Storm Events on Basin-Range Riparian Stream Habitats[1]

William S. Platts, Karl A. Gebhardt, William L. Jackson[2]

Abstract.--Large storm events had major impacts on stream riparian reaches that had received heavy livestock grazing. One ungrazed rehabilitated stream reach actually improved in habitat condition while the two adjacent grazed stream reaches decreased. Each stream reacted differently to channel erosion, with two streams showing mainly lateral channel movement and the third stream vertical channel movement.

INTRODUCTION

This report describes habitat changes in three riparian stream systems from 1978 through 1984. This is a valuable period for analyzing environmental fluctuations because broad areas of the Great Basin experienced some of the lowest and highest stream flows on record.

STUDY AREA

The study streams are in Nevada (Chimney and Gance Creeks) on the northern fringe of the Basin and Range physographic province and in Utah (Big Creek) on the fringe of the middle Rocky Mountain physographic province (fig. 1). Historically the watersheds of all three streams have been heavily grazed by livestock. Complete descriptions of study streams can be found in Platts and others (1983b), Platts and Nelson (1983), and Platts and Nelson[3].

Few flow data exist for Chimney Creek. However, based on a nearby stream record, peak flows in 1984 were in the range of a 500-year flow event (Siebert personal communication). U.S. Geological Survey Records[4] collected on Gance Creek show peak flows of 114 cfs on May 30, 1983, and 127 cfs on May 12, 1984. These flows are approximately 2 to 14 times larger than mean annual discharge peak flows for 1980, 1981, and 1982, which were 60, 9, and 50 cfs, respectively. Flows for Big Creek are not available, but on June 4, 1983, the Bear River that Big Creek empties into, exceeded all past 40-year flow records (Millard and others 1983) at 3630 cfs and was nearly as high in 1984 at 3050 cfs (Harenburg personal communication).

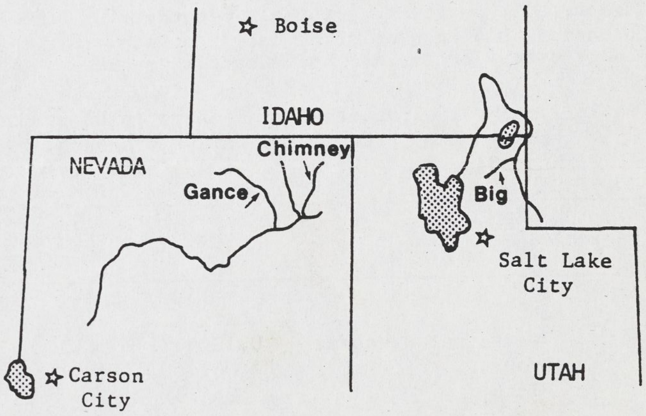


Figure 1.--Study site locations.

---

[1] Paper presented at the North American Riparian Conference, Tucson, Arizona, April 16-18, 1985.

[2] William S. Platts is Research Fisheries Biologist, USDA Forest Service, Intermountain Forest and Range Experiment Station, Boise, Idaho. Karl A. Gebhardt is Hydrologist, Bureau of Land Management, Boise, Idaho. William L. Jackson is Hydrologist, Bureau of Land Management, Denver Service Center, Denver, Colorado.

[3] Platts, W. S., and R. L. Nelson. In press. Stream habitat and fisheries response to livestock grazing and instream improvement structures: Big Creek, Utah. Journal of Soil and Water Conservation.

[4] U.S. Geological Survey. 1984. Unpublished water level records. U.S. Geological Survey. Carson City, Nevada.

METHODS

The basic study design was to randomly select 1,800 ft of stream and subdivide it into 181 transects placed at 10-ft intervals along the stream for location of all data collection. A complete description of the geomorphic, riparian, hydrologic, and fish population methods can be found in Platts and others (1983a), Platts and others (in preparation), and Ray and Megahan (1979).

RESULTS

Chimney Creek

Chimney Creek suffered severe floods in 1983 and 1984 that unraveled the streambanks and made many channel changes (figs. 2 and 3). Table 1 shows the reduction of vegetative overhang in 1984, the year of most severe flooding. In 1981 there was little vegetative overhang, but this was during periods of heavy grazing. In 1982 and 1983, vegetative overhang increased because of two successive years without grazing. Grazing was also minimal in 1984, but the heavy bank scouring still reduced the overhang. The flooding increased fine sediments in the channel, but the scouring flushed gravel downstream and replaced it with rubble. The fines probably re-deposited as flood flows receded. The increased substrate embeddedness rating (1 is high, 5 is low) in 1984 reflected the increase of fine sediments. Chimney Creek became wider and deeper (table 1) after the floods of 1983 and 1984, but pool quality and pool-riffle ratio were reduced.

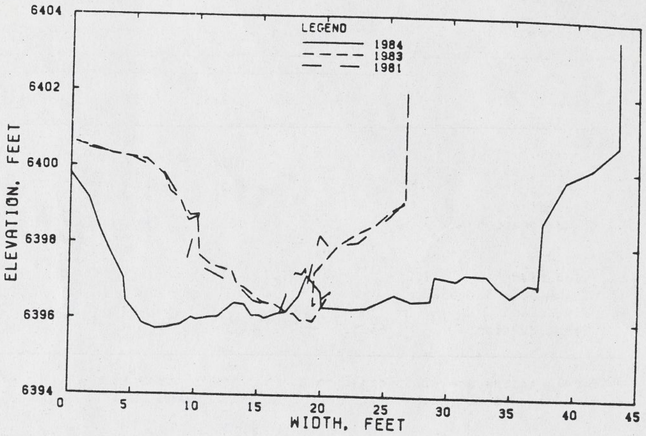
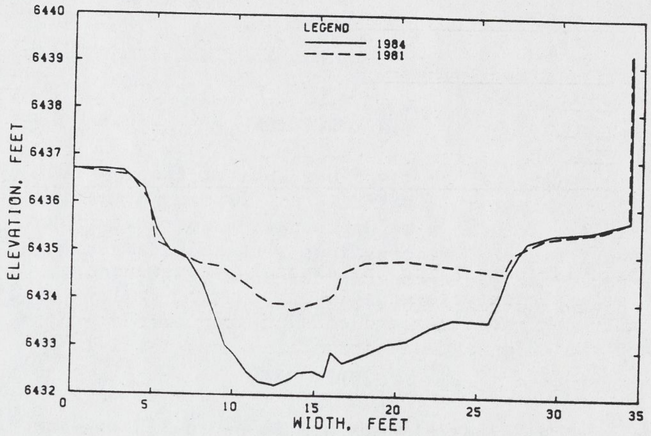


Figure 2.--Chimney Creek channel cross section 31, 1981-84.

Figure 3.--Chimney Creek channel cross section 146, 1981-84.



In years past, the Chimney Creek streamside zone was heavily dominated by large aspen trees. Evidence of this aspen forest still exists in the large amount of decomposing aspen logs in the Chimney Creek channel. The aspen population drastically decreased, probably because of a combination of wind blow down, beaver cutting the large mature trees, and heavy cattle grazing controlling the annual aspen sprouting and seedlings. The large aspen limbs and logs that held the Chimney Creek channel together decreased in volume and decomposed so that they no longer had the capacity to hold the acquired

Table 1.--Physical environmental means (plus or minus 95% confidence about the mean) for the Gance and Chimney study areas. Vegetative overhang, width, and depth in feet; fine sediments and gravel in percent; embeddedness and pool quality in units; and pool-riffle in ratio.

Variable	1978	1979	1980	1981	1982	1983	1984
Gance							
Vegetation overhang	0.10(.03)	0.13(.04)	0.12(.04)	0.11(.03)	0.30(.06)	0.15(.05)	0.06(.03)
Gravel	81 (4)	70 (3)	71 (4)	76 (3.8)	73 (3.6)	64 (3.6)	58 (4)
Width	5.2 (.3)	5.5 (.2)	6.3 (.3)	6.1 (.3)	6.0 (.3)	6.5 (.3)	7.4 (.3)
Chimney							
Vegetation overhang				0.06(.03)	0.16(.04)	0.11(.05)	0.05(.03)
Fine sediments				8.4 (-)	8.5 (-)	6.7 (-)	17.6 (-)
Gravel				57 (3.5)	48 (4.1)	40 (3.9)	18 (2.5)
Embeddedness				3.2 (.1)	2.7 (.1)	3.1 (.1)	1.7 (.1)
Width				4.7 (.3)	4.6 (.3)	5.5 (.3)	6.9 (.4)
Depth				0.15(.01)	0.17(0.02)	0.19(.01)	0.22(.02)
Pool quality				2.8 (.2)	3.1 (.02)	2.4 (.7)	1.8 (.2)
Pool-riffle ratio				2.7 (-)	2.7 (-)	1.7 (-)	1.0 (-)

Table 2.--Some examples of minimum channel elevations in feet and translocation distances[1] in feet at four selected stream transects.

	Year						
	1978	1979	1980	1981	1982	1983	1984
Stream							
Chimney							
Elevation				18		4	35
Translocation				6394.7		6394.7	6386.8
Elevation				9		10	31
Translocation				6395.9		6395.7	6388.3
Gance							
Elevation	11.2		7.7	8.7	4.3		17.1
Translocation	6520.6		6521.2	6521.3	6521.3		6521.3
Elevation		14.5	13	12.5	10.3		9
Translocation		6505.7	6506.7	6506.2	6505.5		6504.4

[1] Translocations are distances from the benchmark stake to the point of minimum channel elevation.

Table 3.--Fish biomass estimates in oz/ft^2 ($x10^{-2}$) for Chimney, Gance, and Big Creeks.

Study Area	1978	1979	1980	1981	1982	1983	1984
Chimney Creek, Nevada - Cutthroat trout							
	-	-	-	0.4	0.6	1.1	0.8
Gance Creek, Nevada - Cutthroat trout							
	1.1	1.6	3.2	2.3	1.2	1.1	1.4
Big Creek, Utah - Rainbow trout							
Site 1	-	0.3	0.7	-	-	-	0.2
Site 2	-	0.4	0.3	-	-	-	0.1
Site 3	-	0.5	0.1	-	-	-	0.2

alluvium underlying the channel. Consequently, large floods were capable of scouring valley alluvium materials and causing accelerated erosion of the Chimney Creek streambanks and channel (table 2).

The Humboldt cutthroat trout (Salmo clarki henshawi) not only survived the floods, but actually had higher summer populations during the high water years of 1983 and 1984 than during the lower water years of 1981 and 1982 (table 3). Drought conditions, which caused Chimney Creek to flow ephemerally, may cause more severe limiting factors than floods. Now that the Chimney Creek channel is largely modified, it will be interesting to see how cutthroat trout summer in Chimney Creek during the next drought years.

Gance Creek

Gance Creek mainly showed vertical change resulting from the major flood events (table 2 and fig. 4). But some cross section profiles (fig. 5 and 6) showed some lateral change. Because of its large vegetative canopy cover and streambank vegetation biomass dominated by trees, the Gance Creek streambanks were more resistant to lateral movement. Had Gance Creek sustained its past control by beaver dams that occurred in the 1950's and 1960's, it would probably have suffered even less from the high flows. The only variables possibly affected by the high flows would have been reduced gravel in the channel (similar to what happened in Chimney Creek), increased stream width primarily because of the higher summer flows, and reduced vegetative overhang.

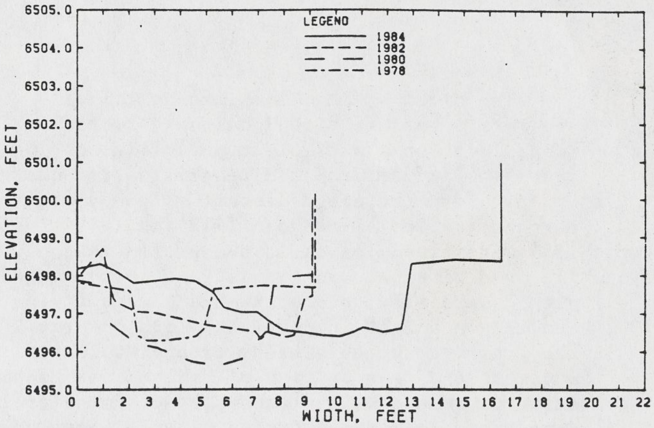
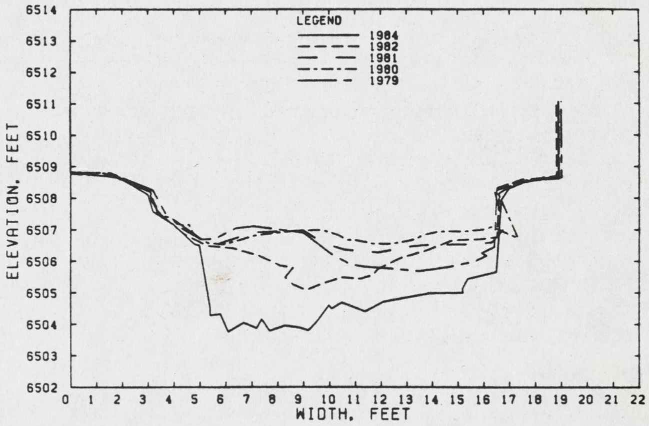


Figure 4.--Gance Creek channel cross section 43, 1978-84.

Figure 5.--Gance Creek channel cross section 89, 1979-84.



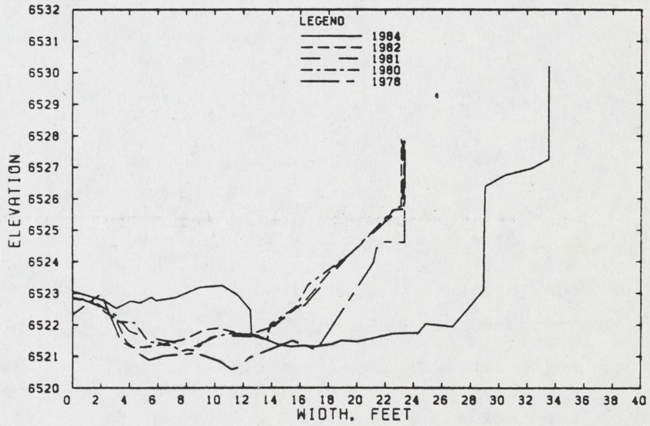


Figure 6.--Gance Creek channel cross section 147, 1978-84.

In Gance Creek the Humboldt cutthroat did best during the drier years of 1980 and 1981. However, the population during the flood years of 1983 and 1984 was quite similar to the lower flow years of 1978 and 1979. Gance Creek has better summer flows than Chimney Creek. Therefore, high flows could have more proportional effect on fish populations.

Big Creek

The sites on Big Creek are described separately because site 2 has been rested (ungrazed) for a sufficient period (about 10 years) to induce dramatic rehabilitative changes. Stream width increased dramatically--by about 40 percent (table 4)--between 1982 and 1984 (1983 and 1984 were flood years) in the grazed reaches. The improved riparian-bank conditions in the ungrazed site 2 were able to contain the excess streamflow, and only a slight increase in width occurred. In the grazed upstream site 3, extensive lateral movement and redeposition of bedload sediments occurred, whereas in grazed site 1, immediately downstream from the ungrazed site 2, there was extensive bank side cutting but reduced deposition of sediments occurred. This combination may have occurred because large volumes of fine sediments were trapped in the rehabilitated riparian zone of the adjacent upstream ungrazed site.

Table 4.--Physical environmental means (plus or minus confidence interval around the mean) for Big Creek. Habitat type and pool quality in units, bank alteration and fine sediments in percent, stream width and streambank undercut in feet, and streambank angle in degrees.

Variable	1978	1979	1980	1982	1984
Habitat type					
Site 1		12.9(0.8)	10.0(0.8)	14.2(0.6)	6.1( )
Site 2		15.3(0.8)	15.3(0.9)	16.5(0.6)	16.2( )
Site 3		11.8(0.8)	13.5(0.8)	14.7(0.6)	8.8( )
Bank alteration					
Site 1		42(-)	69(-)	59(-)	64(-)
Site 2		16(-)	27(-)	25(-)	23(-)
Site 3		34(-)	63(-)	55(-)	64(-)
Fine sediments					
Site 1	15.5()	10.3(-)		21.2(-)	
Site 2	49.9(-)	45.1(-)		39.8(-)	
Site 3	48.1(-)	31.1(-)		34.4(-)	
Width					
Site 1		12.5(0.7)	13.3(0.8)	12.5(0.8)	17.9(1.0)
Site 2		11.7(0.7)	12.3(0.8)	11.7(0.8)	14.0(0.9)
Site 3		12.9(0.7)	13.8(0.8)	13.1(0.8)	18.2(1.8)
Pool quality					
Site 1		2.8(0.3)	3.1(0.3)	3.2(0.3)	3.2(0.3)
Site 2		3.6(0.3)	4.5(0.3)	4.1(0.3)	3.7(0.3)
Site 3		3.1(0.3)	3.9(0.3)	3.6(0.3)	3.2(0.4)
Streambank angle					
Site 1		136 (8)	134 (7)	121 (7)	123 (8)
Site 2		113 (8)	104 (7)	103 (7)	75 (8)
Site 3		138 (8)	124 (8)	125 (7)	125 (8)
Streambank undercut					
Site 1		0.08(.05)	0.10(.05)	0.19(.06)	0.19(.06)
Site 2		0.20(.05)	0.22(.05)	0.29(.06)	0.50(.09)
Site 3		0.07(.05)	0.14(.05)	0.18(.06)	0.23(.06)

Streambank angle (the higher the angle the more the bank is outsloped and the less value the bank has to the fishery) only increased slightly in the grazed sites, but they were already in an outsloped condition. In the ungrazed site, bank angle decreased by 27 percent from 1982 to 1984 to a current value of 75°. The large decrease in bank angle also caused a corresponding 72 percent increase in bank undercut, a move toward better salmonid conditions.

The habitat type (a vegetative classification by form) rating decreased dramatically in the grazed sites because of the large increase in newly eroded sediments dominating the streambank structure and the increase in exposed banks created by lateral movement and bank scour. Streambank alteration was much higher after the floods (1983-84) in the grazed sections but did not change much in the ungrazed section, reiterating the ability of the improved stream-riparian condition in the ungrazed area to resist damage from unusual runoff events.

Heavy recreational fishing pressure effectively reduced trout numbers in site 2 (the livestock exclosure) because of better pool quality. This heavier fishing pressure makes it difficult to evaluate influences on fish populations from recent flooding. It is clear, however, that improved riparian-streambank condition in the ungrazed area has not benefitted the fish population. We believe this is because the large number of instream improvement structures trapped fine sediments, and offsite limiting factors (high water temperatures) from upstream grazed reaches cancel any of the benefits gained (Platts and Nelson[37/]).

CONCLUSIONS

Historically, researchers and managers have been interested in the effects from large flood events (Lyons and Beschta 1983; Gregory and Madew 1982). The runoff years of 1983 and 1984 were intensive, resulting in marginal to dramatic changes in riparian stream habitat of the three study streams. Where streamside vegetation was abundant, flood impacts were minimal.

Major mechanisms leading to changes in channel morphology and thus changes in fishery and riparian habitat, are the resistance of material to fluvial entrainment and the physical destruction of streambanks. These two mechanisms can be controlled, to some extent, by the types of land use and management in the riparian stream zone. If streambank vegetation is reduced, the stream usually responds by an adjustment of channel width. Physical destruction of the streambank results in delivery of sediments to the channel. The initial response of channels to these increased sediments is to reduce bedform roughness (Heede 1980; Jackson and Beschta 1984). In most cases this is accomplished by filling pools with sediments. Subsequent adjustments may include changes in width, depth, meander pattern or longitudinal profile. When these adjustments take place, riparian stream habitats suffer, and fish populations usually suffer.

LITERATURE CITED

Gregory, K. J., and J. R. Madew. 1982. Land use changes, flood frequency and channel adjustment. In: Gravel-Bed Rivers. R.D. Hey, J. C. Bathurst, C.R. Thorne, editors; John Wiley and Sons, N.Y. p 757-781.

Heede, B. H. 1980. Stream dynamics: an overview for land managers, U.S.D.A. Forest Service, General Technical Report RM-12, Rocky Mountain, Forest and Range Exp. Sta., Ft. Collins, CO. 26 p.

Jackson, W. L., and R. L. Beschta. 1984. Influences of increased sand delivery on the morphology of sand and gravel channels. Wat. Res. Bull. 20(4). p 527-533.

Lyons, J. K., and R. L. Beschta. 1983. Land use, floods, and channel changes, Upper Middle Fork Willamette River, Oregon (1936-1980). Water Resources Research, Vol. 19, No. 2. p 463-471.

Millard, M. D., G. A. Birdwell, R. B. Garrett, and G. W. Sandburg. Water Resources Data, Utah, Water Year 1983. U.S. Geological Survey Report UT-83-1, Salt Lake City, Utah.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983a. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service General Technical Report 183, 70 p. Intermountain Forest and Range Experiment Station, Ogden, Utah.

Platts, W. S., and R. L. Nelson. 1983. Population and generic differentiation in the Humboldt cutthroat trout of Gance Creek, Nevada. Cal-Neva Wildlife Transactions, p 15-19.

Platts, W. S., R. L. Nelson, O. Casey, and V. Crispin. 1983b. Riparian-stream-habitat conditions on Tabor Creek, Nevada, under grazed and ungrazed conditions. Western Proceedings: 63rd annual conference of the Western Association of Fish and Wildlife Agencies. p 10-14.

Ray, G. A., and W. F. Megahan. 1979. Measuring cross sections using a sag tape: a generalized procedure. U.S. Forest Service General Technical Report INT-47, Intermountain Forest and Range Experiment Station, Ogden, Utah. 12 p.

Reprinted from: Johnson, R. Roy; Ziebell, Charles D.; Patton, David R.; Ffolliott, Peter F.; Hamre, R. H., tech. coords. Riparian ecosystems and their management: reconciling conflicting uses; Proceedings, first North American riparian conference; 1985 April 16-18; Tucson, AZ. General Technical Report RM-120. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1985: 30-34.

REPRINTED BY USDA FOREST SERVICE
FOR OFFICIAL USE ONLY

North American Journal of Fisheries Management 5:547–556, 1985

Impacts of Rest-Rotation Grazing on Stream Banks in Forested Watersheds in Idaho

WILLIAM S. PLATTS AND RODGER LOREN NELSON

USDA Forest Service
Intermountain Research Station
Forestry Sciences Laboratory
Boise, Idaho 83702

ABSTRACT

Rest-rotation grazing in Idaho allowed forage in the stream-side zone to be used at a higher rate than on either immediately adjacent range or the overall grazing allotment. Stream sides received unauthorized grazing during the scheduled rest periods, however, and complete rest was difficult to achieve. Cattle appeared to graze stream-side meadows at high elevations with less intensity during the early grazing period when vegetation was lush than during the late grazing period. Stream-bank alteration occurred soon after cattle were turned into ungrazed meadows.

Precisely when western stockmen first began to notice a reduction in forage as a result of overused rangelands is not known. Effects of overgrazing, however, were beginning to be recognized as early as 1878 (Box 1979) and the problem was no longer ignored by the turn of the century. By the 1930's, western rangeland conditions were degraded so obviously that Congress passed the Taylor Grazing Act in 1934 to regulate grazing on the public domain; in 1936, the U.S. Department of Agriculture issued its historic letter to the U.S. Senate entitled "The Western Range." This letter stated that deterioration of western rangelands was "so nearly universal under all conditions of climate, topography, and ownership that the exceptions serve only to prove the rule." The political and economic processes were then initiated to begin range rehabilitative efforts in earnest.

Today, many authorities believe that range conditions have improved. Busby (1979), for example, stated that today's rangelands, though possibly in only "fair" condition, are far superior to the denuded rangelands of the 1930's, and Box (1979) believes that western rangelands are presently in their best condition of this century. Appraisals by the Bureau of Land Management (BLM), U.S. Department of the Interior, and the Forest Service (U.S. Department of Agriculture), however, show that riparian lands are still in need of improved management. The BLM estimates that of 217,254 hectares of riparian habitat, 181,086 (83%) were in unsatisfactory condition (Almand and Krohn 1979). The 9.3 million hectares of riparian and wetlands managed by the Forest Service (Owen 1979) are receiving impacts that require prompt attention (USDA Forest Service 1979a).

The noteworthy recovery in overall range condition after the 1930's resulted from a variety of management activities, ranging from reduced livestock stocking rates (numbers per unit area) to special grazing strategies. One of these strategies, rest-rotation grazing, was developed early in this century but was not accepted until Forest Service personnel developed it for use on perennial bunchgrass ranges (Hormay and Evanko 1958; Hormay and Talbot 1961). Rest-rotation grazing is now the primary strategy used on many ranges.

We set up special pastures in ungrazed watersheds so we could follow the effects of rest-rotation grazing by cattle under previously pristine conditions. Additional study areas were situated in allotments that had already been under rest-rotation grazing by cattle for 20 years or more. These two approaches allowed us to look at long-term vs short-term effects, and the effects of this grazing and the timing of grazing on stream-bank stability and riparian vegetation. Some possible solutions for better compatibility between cattle grazing and riparian-stream systems are presented.

REST-ROTATION GRAZING

Under rest-rotation grazing, the grazing area or allotment is partitioned into several pastures. Each pasture is grazed in turn and usually is rested at least 1 year during a grazing cycle. However, in some unusual situations such as periods of low forage production, the pasture scheduled for rest may be grazed anyway at the range manager's discretion (Hormay and Talbot 1961; Hormay 1970). Opinions about the value of rest-rotation grazing vary considerably. Hormay (1970) believes that rest-rotation grazing is a powerful tool for increasing land and vegetative productivity, but W. R. Meiners (in a speech to the Society for Range Management at Tucson, Arizona in 1974) called rest-rotation grazing "a bummer." Blackburn et al. (1982), in a review of grazing impacts on watersheds, offered little support for special grazing strategies.

Ratcliff and Reppert (1974) reported increased vigor of Idaho fescue (*Festuca idahoensis* Elmer) under rest-rotation grazing in California, and Hughes (1979) showed increases in vegetation quality and quantity under rest-rotation grazing in Colorado. Hughes also demonstrated that animal weights could be increased without reducing animal numbers. Gifford and Hawkins (1976), however, surveyed the range management literature and suggested that there is little evidence to indicate that any specialized grazing strategy (including rest-rotation) consistently increased plant cover on watersheds. VanPoolen and Lacey (1979) also analyzed the literature and suggested that, while specialized grazing management usually increases vegetative production, reduction in stocking rates is much more influential. This disparity of opinion results because there is little conclusive evidence to support either line of thinking.

The lack of definitive information to guide multiple-use management is particularly detrimental to proper stream-side management. Hormay and Talbot (1961) made two statements relative to this problem: (1) selective grazing (grazing preferred plants) is one of the principal causes of range deterioration; and (2) under rest-rotation grazing, cattle stocking is based on forage production and use of all available forage, so the degree of use assumes less importance. Thus, under a typical rest-rotation strategy, one would expect the stocking rate to be based mainly on the total production and use of other vegetation that accounts for most of the forage. Because selective grazing causes range deterioration, however, one might reasonably expect continued deterioration of the stream-side vegetation because cattle generally prefer it to that of the drier uplands (uplands are all range types other than riparian). The question of preference has been only superficially addressed so far and needs considerably more research.

Hughes (1979) found that rest-rotation grazing improved range productivity but found no corresponding improvement in riparian conditions. He suggested the fencing of riparian areas. In Utah, Starostka (1979) not only found no stream-side improvement under rest-rotation grazing, but even speculated that the lush riparian growth produced by rest periods caused heavier than normal use of the riparian zone. Platts (1981) also pointed out that even though the ranges have improved since the 1930's, the associated riparian habitat could actually have deteriorated because cattle prefer to graze and rest in riparian zones.

Knowing how stream sides respond to widely used rest-rotation grazing strategies is important because stream-side vegetation is important to fish and wildlife and to the public that uses these areas. The importance of riparian vegetation to wildlife is well-documented by Thomas (1979) and Thomas et al. (1979). Its importance to fish is not necessarily as well appreciated. Furthermore, destructive trampling of the banks probably poses a more serious threat to fish than grazing over the long term. Removal of riparian vegetation which leads to increased erosion, along with trampling, must be evaluated in order to prepare livestock management strategies that will further the goals of multiple-use rangeland management.

STUDY AREAS

Eleven study areas were located in three widely separated tributaries of the Salmon River of central Idaho (Fig. 1), a drainage famous for its chinook salmon (*Oncorhynchus tschawytscha*) and steelhead (*Salmo gairdneri*) production. Climatic conditions in this drainage are severe. Cold snowy winters are routine. Temperatures as low as −50 C have been recorded and annual precipitation runs as high as 1,778 mm (USDA Forest Service 1979b). Considerable rain falls during spring months, but summers generally are warm and dry. Intense storms are common and frost can occur during any month of the year.

All of these areas are located in Forest Service grazing allotments. The study areas on the South Fork Salmon River had not been grazed for 2 decades prior to the study. On the remainder of the study areas, grazing is confined mainly to highly productive, grassy, valley bottoms. The

[sharks]
1986

Shark
Karyotypes
DNA

Comparisons of Karyotypes and Cellular DNA Contents within and between Major Lines of Elasmobranchs

Frank J. SCHWARTZ and Michael B. MADDOCK

Institute of Marine Sciences, University of North Carolina,
Morehead City, North Carolina, U.S.A.

Abstract Several classification schemes have been proposed for elasmobranch fishes. Examination of chromosome number, morphology, and cellular DNA of the major evolutionary lines of living elasmobranchs revealed trends that may help clarify their phylogenetic status. Blood was obtained by direct heart puncture. Chromosome preparations were obtained from short term cultures of blood cells in colcemid. DNA (pg/cell) was measured, after propidium iodide staining, with a flow cytometer.

The data support the assumption that karyotypes with large numbers of chromosomes and including a large proportion of telocentric chromosomes are more representative of the primitive elasmobranch genome than are other karyotypes. *Notorynchus* exhibited the most primitive squaloid karyotype by this criterion (104 chromosomes with 100 telocentrics). *Heterodontus* had the most primitive galeoid karyotype (102 chromosomes with 76 telocentrics). *Rhinobatos* exhibited the most primitive batoid karyotype (92 chromosomes with 48 telocentrics). Variation in DNA content appears to be the result of gene duplication and gene deletion. New findings question some previously reported data on chromosome number.

These observations concerning phylogenetic trends in chromosome number, fundamental number, and DNA content are relevant to speculations on the primitive neoselachian genome: 1) decreasing fundamental number is a major trend in karyotypic evolution in elasmobranchs; 2) a decrease appears to occur in the diploid chromosome number and in the proportion of telocentric chromosomes; and 3) although decreasing DNA content appears to characterize genome evolution in the galeoids, no such trend is apparent in the batoids. Two hypotheses suggested by these observations are discussed.

The classification and phyletic relationships of fishes is constantly changing, being updated, and revised as a result of new findings, methods of study or theories (i.e., Regan, 1929; Berg, 1947; Greenwood *et al.*, 1966; Gosline, 1971; Rosen, 1973). Elasmobranchs, not withstanding, also remain an "unsettled and controversial groupage" of fishes (Compagno, 1977), for several classifications have been proposed to delineate origin, group affiliation, and interrelationships (Müller and Henle, 1838-41; Regan, 1906; Holmgren, 1941; Norman, 1951; Schaeffer, 1967; Schaeffer and Williams, 1977; Zangerl, 1973; Nelson, 1976; and Compagno, 1973, 1977, 1984). Most scientists recognize two to four major assemblages of living sharks and rays: squalomorphs, galeomorphs, squatinomorphs, and batoids.

Although fish chromosomes were first recognized in *Myxine glutinosa* by Retzius (1890), it was not until Roberts (1964) and Denton and Howell (1969) provided squash and flame dry methods for preparing chromosomes that progress was made in determining numbers and

---

Indo-Pacific Fish Biology: Proceedings of the Second International Conference on Indo-Pacific Fishes, edited by T. Uyeno, R. Arai, T. Taniuchi and K. Matsuura, 1986, pp. 148–157, Ichthyological Society of Japan, Tokyo.

karyotypes of fish chromosomes. Further, much progress has been made since McPhail and Jones' (1966) use of gill epithelial examinations in ways to quickly prepare material for chromosome determination, without killing the specimen. Denton (1973) reviewed most of the methods and tissues used to obtain chromosomes and pointed out, "the most elusive technique for getting chromosomes from fishes is that of culturing blood leucocytes." Likewise, most methods then in use depended on the use of colchicine injection and retention of the living specimen for long intervals. This permitted the dispersal of the colchicine into muscles or body organs, prior to the extraction of tissues for chromosome preparation. These limitations made use of colchicine injected sharks marginal, as sharks are temperamental, once captured, difficult to keep alive for lengthy periods of time, require large holding tanks to permit their uninhibited swimming, and are difficult to handle because of their bulk.

Using a colcemid culture technique with blood obtained by cardiac puncture, we have been able to readily determine the karyotypes of 20 species of elasmobranchs. Six karyotypes from primitive species are presented here and others will be reported in subsequent papers. These karyotypes, coupled with DNA determinations, permit us to examine primitive species from major lines of elasmobranch evolution and, together with apparent trends in major lines, to postulate the ancestral genome for neoselachian elasmobranchs in terms of two hypotheses.

Materials and Methods

Heparinized whole blood samples obtained by direct heart puncture were divided into two portions and used for chromosome preparations and cellular DNA analysis. Complete details of the procedures will be described in another paper and are only summarized here.

Metaphase chromosomes were obtained by treating cultures derived from blood samples with 5 μg/ml colcemid for 6–12 hours at 20°C. These samples were subdivided and treated for 20 minutes at 20°C with a series of hypotonic solutions that differed in their osmotic concentrations. Cells were fixed with methanol–acetic acid (3:1), dropped onto glass slides, air-dried, stained with Giemsa (pH = 6.8), and photographed under oil without a cover glass.

Examination of chromosomes obtained from a variety of elasmobranch species (Figs. 1–6 and others) suggested that the chromosomes could be sorted on a qualitative basis into atelocentric (metacentric, submetacentric, and subtelocentric) and telocentric groups; whereas grouping of chromosomes for the purpose of determining the fundamental number (FN) (a form of index, derived many ways, by various authors, i.e. Vasil'yev, 1980) on any other basis would have been somewhat more arbitrary.

Karyotypes were prepared by arranging chromosomes in pairs by size within the atelocentric and telocentric groups. The FN consisted of twice the number of atelocentric plus the number of telocentric chromosomes.

Blood used to determine cellular DNA content was analyzed immediately or washed in phosphate buffered saline modified for elasmobranchs (SPBS) and frozen in SPBS plus glycerol. Chicken erythrocytes were added to each fish erythrocyte sample in a ratio of 1:5, the mixed sample stained with propidium iodide and the distribution of fluorescence of cells in the mixed sample determined with a flow cytometer. DNA values for fish erythrocytes were calculated from the modal fluorescence intensities of fish and chicken erythrocyte populations and the known DNA content of chicken erythrocytes (2.5 pg/cell; pg = picogram). Inconsistencies between the results obtained by this procedure, with different aliquots of the same sample run on different days, suggests that DNA values we report here to be viewed as approximations at present.

Reconciliation Problems

Levan *et al.* (1965) and Denton (1973) noted the confusion and problems related to chromosome terminology, based on position and/or presence of a centromere. Hence, some researchers often referred to macro- and microchromosomes in species where there were discontinuities in chromosome size distributions. Herein, a number of species exhibited karyotypes with very small chromosomes, i.e., *Squatina* or *Rhinobatos* (Figs. 5, 6). We believe a centromere was present on all large chromosomes and in only the very small chromosomes were they difficult to detect (Figs. 5, 6). Since there may be a general tendency for the size of atelocentric chromosomes to increase, possibly at the expense of telocentrics, the very small chromosomes seen in *Squatina* and *Rhinobatos* might not represent microchromosomes, in the sense of Nygren and Jahnke (1972), Ohno *et al.* (1969), or as found in tetrapods (Bernirschke and Hsu, 1975; Ohno *et al.*, 1968) but could be considered to be supernumary **B** or β chromosomes (Denton, 1973; Dingerkus, 1979; Low and Bernirschke, 1972). The interpretation of these small chromosomes is equivocal and may only be resolved by population studies within species exhibiting discontinuities in chromosome size.

Comparing our observations to those reported in the literature by Nygren was difficult because inconsistencies in chromosome number were often found between his mitotic and meiotic chromosome preparations, e.g. *Squalus acanthias*, did not agree (Nygren and Jahnke, 1972; Nygren *et al.*, 1971). We believe these inconsistencies resulted from an inability to distinguish overlapping metaphases. Chromosome morphology by Nygren's and other earlier techniques has generally been inadequate for determining accurate chromosome and fundamental numbers (Makino, 1937; Nygren *et al.*, 1971; Nygren and Jahnke, 1972; Nogusa, 1960; Ohno *et al.*, 1969). These problems were not apparent in Donahue's (1974) or Stingo's (1976, 1979) studies.

Observations

In order to address the problem of interrelationships of the major elasmobranch groups, karyotypes are presented for six species which are considered to be more or less primitive

Fig. 1. Karyotype of *Notorynchus cepedianus* (Sevengill shark), female. 2N = 104, FN = 112, DNA = 8.8 pg/2N. Reference bar = 5 μm.

Fig. 2. Karyotype of *Heterodontus francisci* (Horn shark), female. 2N = 102, FN = 128, DNA = 17.5 pg/2N. Reference bar = 5 μm.

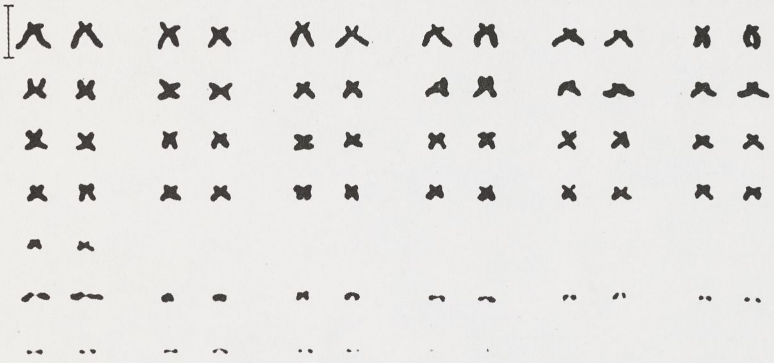


Fig. 3. Karyotype of *Triakis semifasciata* (Leopard shark), sex unknown. 2N = 70–72, FN = 120–124, DNA = 9.6 pg/2N. Reference bar = 5 μm.

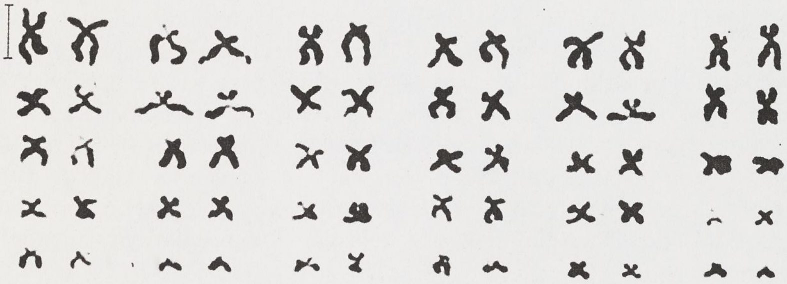


Fig. 4. Karyotype of *Squalus acanthias* (Spiny dogfish), male. 2N = 60, FN = 120, DNA = 14.0 pg/2N. Reference bar = 5 μm.

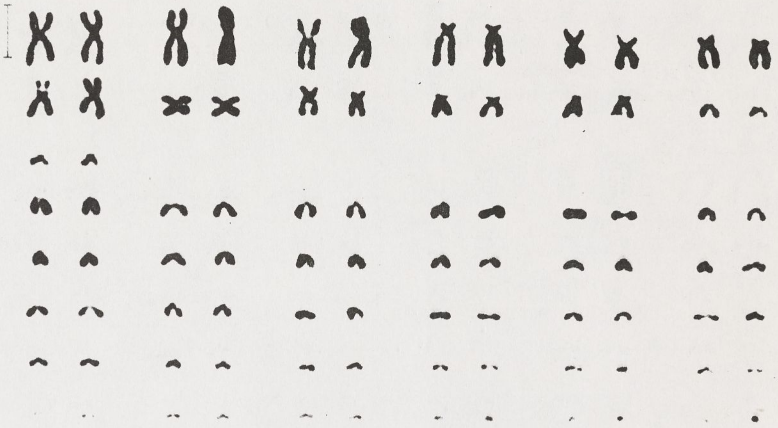


Fig. 5. Karyotype of *Squatina californica* (Pacific angelshark), female. 2N = 88, FN = 114, DNA = 18.6 pg/2N. Reference bar = 5 μm.

Fig. 6. Karyotype of *Rhinobatos productus* (Shovelnose guitarfish), male. 2N = 92, FN = 136, DNA = 8.0 pg/2N. Reference bar = 5 μm.

within these groups (Figs. 1–6). Chromosome numbers (2N), fundamental numbers (FN), and cellular DNA contents are also summarized for these and 14 other species (Table 1). Karyotypes for species listed in Table 1 but not presented here will be published elsewhere. Because of the high chromosome numbers and frequency of small chromosomes in elasmobranch karyotypes, these data should be viewed as approximate, until they can be verified by examination of other individuals from each of the species studied.

From the data presented three observations concerning phylogenetic trends in chromosome number, FN, and DNA content are relevant to speculations on the primitive neoselachian genome.

Observation 1. The fundamental number of the presumably primitive batoid, *Rhinobatos productus,* was higher than the FN of other batoids examined and the FN of the primitive, *Heterodontus francisci,* considered by Compagno (1973) to be a galeoid, is higher

Table 1. Chromosome numbers and cellular DNA contents for 20 elasmobranchs captured in North American Atlantic or Pacific Ocean waters. Data is supplemented by noting geological appearance. (—, no data; Atel., atelocentric; Tel., telocentric; FN, fundamental number)

Species*	Geological** Appearance	2N	Number		FN	DNA (pg/2N)
			Atel.	Tel.		
Notorynchus cepedianus	Middle Jurassic	104	8	100	112	8.8
Heterodontus francisci	Upper Jurassic	102	26	76	128	17.5
Carcharodon carcharias	Upper Cretaceous	82	48	34	130	12.9
Cephaloscyllium ventriosum	Upper Cretaceous	64	46	18	110	18.1
Carcharhinus acronotus	Eocene	84	32	52	116	7.3
Carcharhinus limbatus	Eocene	80 ±	30 ±	50 ±	110 ±	7.8
Galeocerdo cuvieri	—	86	38	48	124	8.3
Rhizoprionodon terraenovae	—	80 ±	44 ±	36 ±	124 ±	7.2
Triakis semifasciata	Oligocene	70–72	52	18–20	122–124	9.6***
Sphyrna lewini	Upper Cretaceous	78	18	60	95	6.6
Squalus acanthias	Upper Cretaceous	60	60	0	120	14.0
Squatina californica	Upper Jurassic	88	26	62	114	18.6***
Platyrhinoidis triseriata	—	64	32	32	96	15.5
Rhinobatos productus	Upper Jurassic	92	44	48	136	8.0
Raja eglanteria	Cretaceous	58	30	28	88	6.5
Gymnura micrura	—	56	44	12	100	11.4
Urolophus halleri	—	72	20	52	92	13.0***
Myliobatis californica	Cretaceous	52	50	2	102	10.4
Myliobatis freminvillei	Cretaceous	52	50	2	102	10.6
Rhinoptera bonasus	Cretaceous	64	42	22	106	10.0

* Species listed follows Robins *et al.* (1980).
** Geologic period for appearance of earliest fossil form as given in Bigelow and Schroeder (1948, 1953).
*** DNA data of Hinegardner (1976).

than that of other galeoids except the white shark, *Carcharodon carcharias* (Table 1). Consequently, these data suggest that decreasing fundamental number is a major trend in karyotype evolution in elasmobranchs. This general trend is also apparent in other vertebrate groups (Dingerkus, 1979).

Observation 2. The diploid chromosome numbers of *Rhinobatos productus* and *Heterodontus francisci* are higher than the chromosome numbers of other more advanced batoids and galeoids respectively (Table 1). The lower diploid numbers of more advanced species are not only the result of lower fundamental numbers but also of decreased proportions of telocentric chromosomes, compared to atelocentric chromsomes. Furthermore, the karyotype of *Notorynchus cepedianus* is composed primarily of telocentric chromosomes. Thus, a second general trend in the evolution of elasmobranch karyotypes appears to be a decrease in the diploid chromosome number and in the proportion of telocentric chromosomes.

Observation 3. The DNA content of *Heterodontus francisci* was high compared to some of the more advanced galeoids, but that of *Rhinobatos productus* was low compared to a number of more advanced batoids. Thus, although decreasing DNA content appears to characterize genome evolution in the galeoids, no such trend was apparent in the batoids.

Discussion

Chromosome numbers, many of dubious accuracy, are now known, for between 1000 and

1500 species of the 20–22,000 fishes that inhabit the world (Cohen, 1970). Elasmobranchs account for 15 of this total (Vasil'yev, 1980; Ojima, 1985). Likewise, of the 306 fishes whose cellular DNA is known, only 45 are elasmobranchs (Hinegardner, 1976; Hinegardner and Rosen, 1972; Stingo, 1979).

With the development of our cardiac puncture blood culture technique, we have been able to determine the chromosome numbers for 20 elasmobranchs without having to sacrifice or maintain the specimen in confinement. We stressed examination of species within the four (although in 1973 Compagno suggested a fifth group: heterodontoid-orectolobid and lamnoid-carcharhinid, derived independently from each other) superorders of living elasmobranchs recognized by Compagno (1973, 1977): squalomorphii, squatinomorphii, galeomorphii, and batoidea, in order to address the problems of origin and how members of those superorders were related. Nelson's (1976) recognition of only three superorders contrasts with the four superorders of Compagno (1973) or the four orders recognized by Robins *et al.* (1980).

Compagno (1977) considered the hexanchids to be within the squalomorphs and not as primitive as others have suggested. He likewise considered *Heterodontus* to be within the galeomorphs. *Squatina,* a squatinomorph, was a specialized ray-like shark (Compagno, 1973, 1977). He also divided the batoids into five groups: rhinobatoids, rajoids, pristoids, torpedinoids, and myliobatoids, with the rhinobatoids being the basal group for all other ray groups. Skates were believed to be offshoots from the rhinobatoids and the myliobatoids were

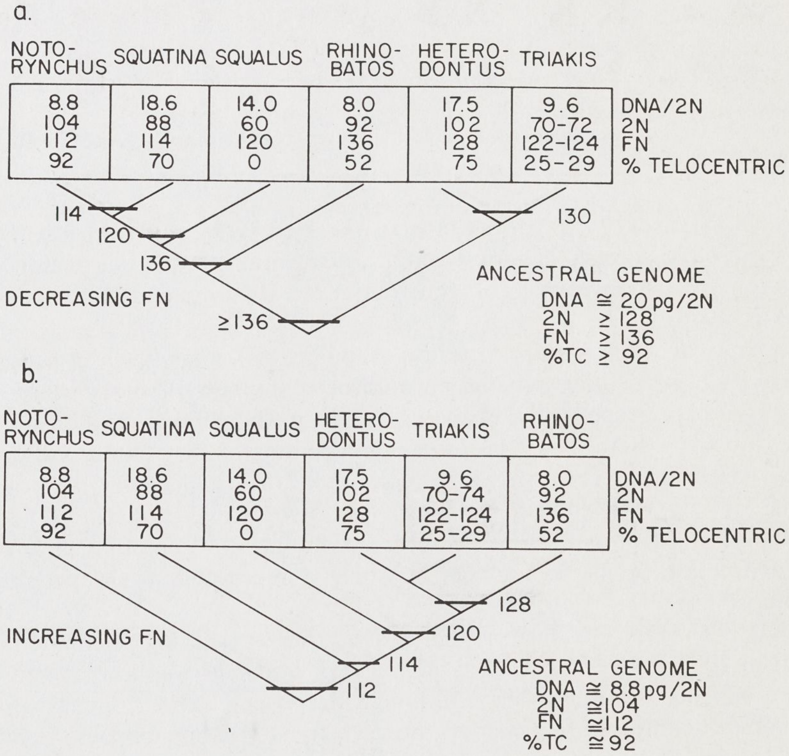


Fig. 7. Hypothetical phylogenetic relationships based on the assumption of decreasing phylogenetic parameters (a), and that based on the assumption that the cytogenetic parameters of *Notorynchus cepedianus* best approximate those of the ancestral genome of living elasmobranch (b).

considered to be the most derived batoid. Compagno (1973) prefers to think that all elasmobranchs were independently derived from a basal neoselachian stock.

Unfortunately for our phylogenetic considerations the values of the cytogenetic parameters suggested by our data to be primitive (i.e., high FN, high 2N and proportion of telocentric chromosomes, and high DNA content) did not correspond to a sufficient degree, in any of the primitive species examined, to suggest an unequivocal hypothesis concerning the structure of the ancestral neoselachian genome or the cytogenetic changes that accompanied the derivation of extant elasmobranch groups from such an ancestor. Nevertheless, when simplifying assumptions are made, a number of hypotheses based on our cytogenetic data are possible. Two such hypotheses are presented:

Hypothesis 1 (Fig. 7a) assumes that, through time, although eupolyploidy was probably involved in the origin of the ancestral neoselachian genome from more primitive chondrichthian ancestors, eupolyploidy was not involved in the derivation of extant genomes from their most recent common ancestor. Hypothesis 1 further assumes that the derivation of extant genomes involved decreases in FN, 2N and proportion of telocentric chromosomes, and cellular DNA content from an ancestral genome with high values for each of these parameters. Hypothesis 1 finally assumes that the galeoid sharks are a sister group to all other living elasmobranch groups examined.

Hypothesis 2 (Fig. 7b) does not rule out the possible involvement of eupolyploidy followed by diploidization in the origin or elaboration of the major elasmobranch groups from some common ancestor. Under this assumption the proportion of telocentric chromosomes might be a more conservative parameter than the NF. Thus, the genome of *Notorynchus*, among the species we have examined, could represent most accurately the genome of the ancestral species from which other groups were derived. Hypothesis 2 assumes that the ancestral genome for living elasmobranchs was similar to that of *Notorynchus* in FN, 2N, and proportion of telocentric chromosomes, and DNA content and the origin of the ancestral squaloid, batoid, and galeoid genomes involved an increase in the FN.

Analysis of hypothesis 1: Under this hypothesis the ancestral genome for living elasmobranchs possessed a high FN ($\geqslant 136$), high 2N ($\geqslant 128$) and proportion of telocentric chromosomes ($\geqslant .92$) and high DNA content ($\geqslant 20$ pg/2N). Thus, the primitive species that we have examined exhibited a mosaic of primitive and derived values for these cytogenetic parameters. *Notorynchus* was primitive for proportion of telocentric chromosomes (0.92) but derived for FN (112) and DNA content (8.8 pg/2N; Fig. 1). We have used the expression pg DNA/2N to refer to the cellular DNA content G_0 or G_1 diploid cells. *Heterodontus* was primitive for FN (128), proportion of telocentrics (0.75), and DNA content (17.5 pg/2N; Fig. 2). *Triakis* was derived with respect to FN (122–124), proportion of telocentrics (0.25–0.29) and DNA content (9.6 pg/2N; Fig. 3). *Squalus* was primitive for FN (120) and DNA content (14.0 pg/2N) but derived for proportion of telocentric chromosomes (0; Fig. 4). *Squatina* was primitive for proportion of telocentric chromosomes (0.70) and DNA content (18.6 pg/2N; Fig. 5), but derived for FN (114). *Rhinobatos* was primitive for FN (136) but derived with respect to the proportion of telocentric (0.52) and DNA content (8.0 pg/2N; Fig. 6). Surprisingly, *Squatina* and *Notorynchus* were more closely related by this hypothesis than might be conceded by some morphologists.

Analysis of hypothesis 2: Geological data and the conclusions of some morphological studies have suggested that the hexanchids (*Notorynchus*) could be very primitive elasmobranchs with a separate and perhaps remote origin from that of other extant groups. If this conclusion is true and these species have been "frozen" in their level of diversification for 150×10^6 years (Schaeffer, 1967), then they might represent an earlier stage in the phylogeny of elasmobranch genomes than other living species. Consequently the number of genomic changes separating the major groups of living elasmobranchs, including perhaps cycles of eupolyploidy followed by diploidization, might be greater than envisioned under Hypothesis 1. The residual effects of polyploidy followed by diploidization in the evolution of the chordates appear to be increased DNA and increased FN.

Hypothesis 2 was constructed to examine major elasmobranch group relationships, based on an increasing FN in the primitive species. Under this hypothesis *Rhinobatos, Triakis, Squalus,* and *Heterodontus* are derived species with respect to FN and *Squatina* along with *Notorynchus* are primitive. Although Hypothesis 2 is more satisfying from the point of view of Compagno's studies (1973, 1977), Hypothesis 1 appears more probable in relation to the genetic mechanisms assumed. Of course other hypotheses based on our cytogenetic data are possible.

The batoids and galeoids have been reasonably well represented in our studies but the squaloids, hexanchids, and batoids were each represented by a single species. Consequently we have been unable to estimate the extent of variation of the values of cytogenetic parameters between species in these groups and unable to identify phylogenetic trends in these groups by which we could extrapolate to the cytogenetic parameters of ancestral squaloids, hexanchoids, or squatinoids. Additional data from even a single species from each of these groups (a single species from the hexanchoids and squatinoids is all that can reasonably be expected from North American waters) might provide valuable insights into the value of conventional cytogenetic data for reconstructing elasmobranch phylogeny.

Acknowledgments

We thank the following who were helpful in either the field or laboratory, or supplied study specimens: O. Lewis, J. Purifoy, and G. Safrit, Institute of Marine Sciences, University of North Carolina; Dr. S. Haskill, University of North Carolina Medical School; Dr. M. Stoskoff, National Aquarium, Baltimore, Maryland; Dr. J. McCosker, Steinhart Aquarium, San Francisco, California; R. West, Scripps Aquarium, Scripps Institution of Oceanography, La Jolla, California. Dr. W. Hamlett, Medical College of Ohio, Toledo, reviewed the manuscript. Brenda Bright typed the text.

Literature Cited

Berg, L. S. 1947. Classification of fishes, both recent and fossil. J. Edwards, Ann Arbor, Michigan, Translation, 517 pp.

Bernirschke, K. and T. C. Hsu, eds. 1975. Chromosome atlas: fishes, amphibians, reptiles, and birds. Vol. 3, Various fishes. Springer Verlag, New York, 14 pp.

Bigelow, H. B. and W. C. Schroeder. 1948. Fishes of the Western North Atlantic. Pt. 1, Lancelets, cyclostomes, and sharks. Sears Found. Mar. Res. Mem. 1. Yale Univ., New Haven, Connecticut, 576 pp.

——— and W. C. Schroeder. 1953. Sawfishes, guitarfishes, skates and rays. Pages 1–514 *in* J. Tee-Van *et al.*, eds. Fishes of the Western North Atlantic. Part 2. Sears Found. Mar. Res., New Haven.

Cohen, D. M. 1970. How many recent fishes are there. Proc. Calif. Acad. Sci., 38 (17): 341–345.

Compagno, L. J. V. 1973. Interrelationships of living elasmobranchs. Pages 15–61 *in* P. H. Greenwood, R. S. Miles and C. Patterson, eds. Interrelationships of fishes. Zool. J. Linn. Soc. London, Vol. 53 (suppl. 1). Academic Press, New York.

———. 1977. Phyletic relationships of living sharks and rays. Amer. Zool., 17 (2): 303–322.

———. 1984. Sharks of the world. Pt. 1. FAO Fish Synop. (125), 4 (1): 1–249.

Denton, T. E. 1973. Fish chromosome methodology. Charles C. Thomas Company, Springfield, Illinois, 166 pp.

——— and W. M. Howell. 1969. A technique for obtaining chromosomes from the scale epithelium of teleost fishes. Copeia, 1969 (2): 392–393.

Dingerkus, G. 1979. Chordate cytogenetic studies: an analysis of their phylogenetic implications with particular reference to fishes and the living Coelacanth. Occas. Pap. Calif. Acad. Sci., (134): 1–17.

Donahue, W. H. 1974. A karyotypic study of three species of rajiformes (Chondrichthyes, Pisces). Can. J. Genet. Cytol., 16: 203–211.

Greenwood, P. H., D. E. Rosen, S. H. Weitzman and G. S. Myers. 1966. Phyletic studies of teleostean fishes, with a provisional classification of living forms. Bull. Amer. Mus. Nat. Hist., 131: 339–456.

Gosline, W. A. 1971. Functional morphology and classification of teleostean fishes. Univ. Hawaii Press, Honolulu, Hawaii, 208 pp.

Hinegardner, R. T. 1976. The cellular DNA content of sharks, rays, and some other fishes. Comp. Biochem. Physiol., 55B: 367–370.

——— and D. E. Rosen. 1972. Cellular DNA content and the evolution of teleostean fishes. Amer. Nat., 106: 621–644.

Holmgren, N. 1941. Studies on the head of fishes. Pt. 2. Comparative anatomy of the adult selachian skull, with remarks on the dorsal fins in sharks. Acta Zool. Stockholm, 22: 1–100.

Levan, A., K. Fredga and A. A. Sandberg. 1965. Knowledge for centromeric position on chromosomes. Hereditas, 52: 201–220.

Low, R. J. and K. Bernirschke.1972. Microchromosomes in the American red fox, *Vulpes fulva*. Cytologia, 37: 1–11.

Makino, S. 1937. The chromosomes of two elasmobranch fishes. Cytologia (Fijii Jub. Vol.), 2: 867–876.

McPhail, J. D. and R. L. Jones. 1966. A simple technique for obtaining chromosomes from teleost fishes. J. Fish. Res. Bd. Canada, 23 (5): 767–768.

Müller, J. and F. G. Henle. 1838–1841. Systematische beschreibung der Plagiostomen I-LXII. Veit and Company, Berlin, 200 pp.

Nelson, J. S. 1976. Fishes of the world. J. Wiley and Sons, New York, 416 pp.

Nogusa, S. 1960. A comparative study of chromosomes in fish with particular consideration on taxonomy and evolution. Mem. Hyogo Univ. Agric., 3 (1): 1–62.

Norman, J. R. 1951. A history of fishes. A. A. Wyn, New York, 463 pp.

Nygren, A. and M. Jahnke. 1972. Microchromosomes in primitive fishes. Swedish J. Agric. Res., 2: 229–238.

———, B. Nilsson and M. Jahnke. 1971. Cytological studies in Hypotremata and Pleurotremata (Pisces). Hereditas, 67: 275–282.

Ohno, S., J. Muramoto, C. Stenius, L. Christian, W. A. Kittrell and N. B. Atkin. 1969. Microchromosomes in Holocephalian, Chondrostean, and Holostean fishes. Chromosoma (Berlin), 26: 35–40.

———, U. Wolf and N. B. Atkin. 1968. Evolution from fishes to mammals by gene duplication. Hereditas, 59 (1): 169–187.

Ojima, Y. 1985. Fish chromosome data retrival list 1985. Kwansei Gakuin Univ., Ojima Lab., Nishinomiya, Japan, 335 pp.

Regan, C. T. 1906. A classification of the selachian fishes. Proc. Zool. Soc. London, 1906: 722–758.

———. 1929. Fishes. Encyclopedia Britanica, 14 ed., 7: 305–329.

Retzius, G. 1890. Über Zellentheilung bei *Myxine glutinosa*. Biol. Foren. Forknoll. (Stockholm), 2: 80–91.

Roberts, T. L. 1964. A chromosome study of twenty species of Centrarchidae. J. Morph., 115: 401–418.

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea and W. B. Scott. 1980. A list of the common and scientific names of fishes from the United States and Canada. Am. Fish. Soc., Spec. Publ. 12 (4th ed.), Bethesda, Maryland, 174 pp.

Rosen, D. E. 1973. Interrelationships of higher euteleostean fishes. Pages 397–513 *in* P. H. Greenwood, R. S. Miles and C. Patterson, eds. Interrelationships of fishes. Zool. J. Linn. Soc., 53 (suppl. 1). Academic Press, New York.

Schaeffer, B. 1967. Comments on Elasmobranch evolution. Pages 3–35 *in* P. Gilbert, R. Mathewson and D. Rall, eds. Sharks, skates and rays. The Johns Hopkins Press, Baltimore, Maryland.

——— and W. Williams. 1977. Relationships of fossil and living elasmobranchs. Amer. Zool., 17: 293–302.

Stingo, V. 1976. Cariologia di due torpedini italiana. Boll. Zool., 43 (4): 406–407.

———. 1979. New developments in vertebrate cytotaxonomy. II. The chromosomes of the cartilagenous fishes. Genetica, 50 (3): 227–239.

Vasil'yev, V. P. 1980. Chromosome number of fishes and fish like animals. Vopr. Ikthiol., 20 (3): 387–422.

Zangerl, R. 1973. Interrelationships of early chondrichthyeans. Pages 1–15 *in* P. H. Greenwood, R. S. Miles and C. Patterson, eds. Interrelationships of fishes. Zool. J. Linn. Soc., 53 (suppl. 1). Academic Press, New York.

遗传学报，13（6）：470--475，1986
Acta Genetica Sinica

空气负离子对 γ-射线诱发小鼠染色体畸变和 SCE 防护作用的研究1）

郭学聪 刘凌云 刘 彦 狄少杰 费 青
（北京师范大学生物系）

周瑞英 谢 林2） 郭 玥3）
（北京师范大学低能核物理研究所）

鉴于空气负离子对医疗保健有良好效应，而对染色体和 DNA 起什么作用尚缺乏研究，要直接研究空气负离子对染色体 DNA 的作用较为困难，因此，本文试图通过辐射效应探索空气负离子的作用。应用空气负离子处理昆明小白鼠 70 天，再用 γ- 射线照射动物。辐照后分 9 个不同时间取样，分析小鼠骨髓细胞染色体畸变和 SCE 等的变化。结果表明空气负离子对辐射诱变具有防护作用。

空气负离子是带负电的一些大小不同的分子原子群。一些学者认为其中的负氧离子对机体具有特别良好的作用。三十年代开始研究负离子治疗疾病，七十年代空气负（氧）离子发生器为国际专利[25]认可后，负离子的应用和生物效应的研究，引起了更广泛地重视[21-23]。我国近年来也相继研制了多种空气负离子（初时称负氧离子）发生器，并试验应用于医疗保健[1-11]。1983 年 3 月在北京召开了全国性的负氧离子发生器技术评议和学术交流会。鉴于空气负离子对医疗保健有良好效应，但对生物的染色体、DNA 起什么作用尚缺乏研究，空气负离子的作用较为温和微弱，要直接研究它对染色体、DNA 的作用较为困难，因此，本文通过辐射效应探索了空气负离子对辐射诱变的防护作用。

材料和方法

实验用昆明小白鼠，均为雄性，购自中国医学科学院实验动物中心。实验小鼠 302 只，体重大多数为 10—13 克。将各同级重量的小鼠随机分为 6 笼，饲养于专为研究空气负离子的生物效应而设计建造的动物饲养室内。饲养室一间供空气负离子，一间供与空气负离子发生器等流量风的正常空气，其它实验条件完全一致，都有空调机和通气装置。鼠笼是用镀有不吸收空气负离子的材料制成的。处理实验动物 70 天。利用中国科学院生物物理所钴 $^{60}\gamma$-射线进行辐照，剂量率 62.65rad/分。预备实验剂量分别为 100、200、300、400、500、600 和 700rad，正式实验均为 100rad。

本文于 1985 年 5 月 10 日收到。

1）本文由中国科学院生物物理所葛兆华同志协助辐照小鼠；马郁芳同志参加部分镜检工作，在此一并致谢。

2）现在北京空气负离子研究所。

3）现在北京太阳能研究所。

表1 空气负离子对 γ-射线诱发小鼠骨髓细胞染色体畸变作用的数据

Table 1 Data of the effects of air negative ions on chromosomal aberrations induced by γ-rays in mouse bone marrow cells

辐照后取样时间 Sampling time after irrad. (h)	负离子(N) 空气(A) Negative ions(N) Air(A)	小鼠数 No. of mice	分析细胞数 No. of Cells analysed	染色单体断裂 Chromatid breaks			染色单体交换 Chromatid exchanges			染色体断裂 Chromosome breaks			微小体 Minutes			双着丝点体 Dicentrics			染色体环 Chromosome rings			总畸变数$^{2)}$ Total chromosome aberrations		
				数 No.	%	$P^{1)}$	数 No.	%	$P^{1)}$	数 No.	%	$P^{1)}$	数 No.	%	$P^{1)}$	数 No.	%	$P^{1)}$	数 No.	%	$P^{1)}$	数 No.	%	$P^{1)}$
2	N	2	402	125	31.09	<0.05	1	0.25		41	10.20	>0.05	29	7.21	>0.05	—			6	1.49	>0.05	209	51.99	<0.05
	A	2	400	151	37.75		—			39	9.75		38	9.50		—			7	1.75		242	60.50	
4	N	5	935	348	37.22	<0.001	10	1.07	<0.05	105	11.23	<0.001	88	9.41	<0.05	3	0.32	>0.05	19	2.03	<0.01	605	64.71	<0.001
	A	4	699	343	49.07		17	2.42		139	19.89		88	12.59		4	0.57		30	4.29		672	96.14	
8	N	4	707	227	32.11	<0.05	8	1.13	>0.05	117	16.46	<0.05	71	10.04	<0.05	3	0.42		29	4.10	<0.05	491	69.45	<0.001
	A	4	540	204	37.78		6	1.11		115	21.30		74	13.70		—			36	6.67		477	88.33	
12	N	4	711	157	22.08	<0.001	5	0.70	<0.05	108	15.19	<0.001	92	12.94	>0.05	7	0.98	<0.05	27	3.80	<0.05	435	61.18	<0.001
	A	4	784	276	35.20		15	1.91		182	23.21		87	11.10		18	2.30		52	6.63		715	91.20	
16	N	3	572	148	25.87	>0.05	1	0.17	>0.05	68	11.89	<0.05	37	6.47	<0.05	2	0.35	>0.05	25	4.37	>0.05	309	54.02	<0.001
	A	3	530	137	25.85		4	0.75		90	16.98		52	9.81		2	0.38		29	5.47		349	65.85	
20	N	4	797	86	10.79	<0.001	—			103	12.92	>0.05	35	4.39	<0.05	1	0.13		29	3.64	<0.05	284	35.63	<0.001
	A	4	808	140	17.33		—			87	10.77		54	6.68		—			47	5.82		375	46.42	
24	N	3	502	58	11.55	<0.001	—			13	2.59	<0.05	14	2.79		3	0.60	>0.05	17	3.37	>0.05	125	24.90	<0.001
	A	2	363	85	23.42		2	0.55		20	5.51		—			5	1.38		14	3.86		147	40.50	
36	N	3	506	31	6.73	<0.05	—			15	2.96	<0.01	9	1.78	>0.05	1	0.20	>0.05	14	2.77	>0.05	85	16.80	<0.01
	A	3	511	49	9.59		1	0.20		34	6.65		11	2.15		4	0.78		12	2.35		128	25.05	
48	N	5	908	65	7.16	>0.05	2	0.22	>0.05	25	2.75	>0.05	3	0.33	<0.01	1	0.11		7	0.77	<0.01	113	12.44	>0.05
	A	3	707	41	5.80		2	0.28		23	3.25		13	1.84		—			18	2.55		117	16.55	

1) *t* 测验（*t*-test).

2) 每个交换、双着丝点和环畸变均算 2 个畸变。 Each of the exchange, dicentric and ring aberrations is scored as two aberrations.

辐照后分别于2、4、8、12、16、20、24、36和48小时取样，脱颈处死动物，取骨髓细胞进行染色体制片，显微镜检，并进行统计分析。具体方法见我们以前的工作[12]。

结果

实验结果见表1、2和图版I。由表1看出，染色单体断裂(图版I, 2—4)和染色体断裂(图版I, 3)，都是空气负离子处理组比空气对照组断裂的频率为低。微小体(表1、图版I, 2)总的看也是空气负离子处理者频率较低。染色体环(图版I, 6)的畸变频率也表现出同样的效果。从而可看出，前三者的辐射一击畸变和后者的二击畸变都显示出空气负离子对辐射诱变损伤的防护效应。

表1的双着丝点体(图版I, 7)和染色单体交换形成三射体、四射体(图版I,4、5)，负离子处理组与空气对照组相比，其规律性不明显。四倍体(图版I, 9)亦然。这可能与数目较少波动较大有关。但总的畸变率(表1)，空气负离子处理组显著地低于空气对照组。

表2 空气负离子对 γ-射线诱发小鼠骨髓细胞 SCE 作用的数据

Table 2 Data of the effects of air negative ions on SCEs induced by γ-rays in mouse bone marrow cells

辐照后取样时间 Sampling time after irrad.(h)	负离子(N) 空气(A) Negative ions (N) Air (A)	小鼠数 No. of mice	姊妹染色单体交换 Sister chromatid exchanges				
			SCD 细胞数 No. of SCD cells	SCE 总数 Total SCEs	SCE/细胞 SCE/Cell	SCE/染色体 SCE/chromosome	
						%	P1)
4	N A	5 4	39 35	101 119	2.59 3.40	6.47 8.50	<0.05
8	N A	4 4	122 70	372 332	3.05 4.74	7.62 11.86	<0.001
16	N A	3 3	32 19	103 69	3.22 3.63	8.05 9.08	>0.05
20	N A	4 4	41 140	105 472	2.56 3.37	6.40 8.43	<0.01
24	N A	3 2	68 —	111 —	1.63 —	4.08 —	
36	N A	3 3	254 211	448 522	1.76 2.47	4.41 6.18	<0.001
48	N A	5 3	342 421	616 951	1.80 2.26	4.50 5.65	<0.001

1) t 测验 (t-test).

由表2可以看出，SCE (图版I, 4、8) 频率也是空气负离子处理组低于空气对照组，显示空气负离子对DNA辐射损伤有一定的防护作用。

讨　论

我们所观察研究的畸变，包括染色单体畸变和染色体畸变。前者一般是当细胞进入晚 S 期或 G_2 期受辐照而引起的畸变。因为晚 S 期和 G_2 期从 DNA 分子水平上考虑，一般说染色体复制为两个染色单体，辐射损伤常只涉及染色单体。如果在 G_1 期或早 S 期染色体尚未复制，这时的辐射损伤一般则引起染色体畸变。利用这两类畸变作为估价空气负离子对辐射诱变的防护效应是适宜的。由我们的实验结果可以看出，这两类畸变都显示出空气负离子对辐射诱变的防护作用。

从表 1 数据还可以看出，染色单体断裂频率高于染色体断裂频率。如果以每个细胞的断裂数作为衡量指标，它可以说明 G_2 期一般比 G_1 到早 S 期对辐射更敏感。对这种敏感性来说，我们的实验结果和其他学者在人和其它生物所获结果是一致的[14,18,19,24]。从表 1 数据还能看出，染色单体断裂高峰在辐照后 4 小时，而染色体断裂高峰有后移的趋向。这可能与不同时相的细胞进程遭受辐照后其延缓程度不同有关。细胞受辐照后，其细胞周期的进程受到抑制而延缓，可一直延缓到 48 小时或更长。不同时相的细胞延缓程度不同。Dewey 和 Robinette[15] 认为 S 期辐照的细胞延缓较长。这些畸变主要是由辐照时的非同步细胞群体而产生的，其持续时间又是异质的，所以在不同时间取样表现出不同的畸变频率。此外，由表 1 微小体、染色体环和总畸变率也能说明空气负离子对辐射诱变的防护作用，总畸变率的表现最为明显。

姊妹染色单体交换（SCE）一般不把它属于染色体畸变，它的形成与染色体畸变的形成机理不同。SCE 频率能反映染色体 DNA 损伤修复的程度，因而它是检测诱变物和致癌物的一种灵敏手段和指标，它能比畸变敏感二百倍[20]。也有些学者的工作表明辐射对 SCE 的频率没有什么影响[18]，但他们是在辐射后 72 和 96 小时所得结果。在我们的实验中，辐照对 SCE 是有作用的，从表 2 每条染色体的 SCE 看，空气负离子处理组比空气对照组者为低，表明空气负离子对 DNA 辐射损伤有防护作用。

一些实验证明，氧的浓度对辐射效应影响很大，有机体缺氧能减轻辐射症状，缺氧能为细胞提供一定程度的辐射防护。Giles 等[17] 发现随着空气中氧浓度增高，畸变率明显增高。Alper[13] 认为潜在的染色体断裂在有氧情况下很容易转变为真正的断裂；在缺氧情况下潜在的断裂可得到修复。我们的实验表明空气负离子（其中包括负氧）对辐射诱变有防护作用，但是这与上述氧效应并不矛盾，因为用负（氧）离子发生器长时间（70 天）处理实验动物，与用同样流量正常空气风同样长的时间处理对照动物，两个实验室的空气氧含量是一致的。二者的氧浓度相同，而表现出的防护效应，看来可以归因于空气负离子，特别是其中的负氧离子。空气中氧的比例虽比氮少得多（氧：氮约为 1:4），但从该二元素的电子亲合势和电负性（electronegativity）来说，氧的电子亲合势（O 为 1.465，N 为 0.0）和电负性（O 为 3.5，N 为 3.0）都比氮大，所以负氧离子的比例可能比负氮离子大得多。

Emerit 等[16] 认为 O_2^- 能使染色体畸变率和 SCE 频率增加，认为 O_2^- 能加重 DNA 的辐射损伤，是引起染色体畸变的内源性致变剂。他们的实验是在辐照时将水暴露于高能辐射下增加 O_2^- 的，而我们的实验，空气负离子（包括 O_2^-）处理是在辐照之前，而辐照时又是在正常空气中。我们和 Emerit 等的实验条件不同，所以效果也不一样。

关于空气负离子对辐射诱变防护的机理，尚不清楚。看来，空气负离子的作用可能是多方面的，可能是通过呼吸系统、通过细胞膜进入机体细胞内，影响细胞膜电位的变化，影响线粒体的电子传递和能量转换等，对遗传物质染色体 DNA 的稳定、对基因表达、对增强细胞代谢活性等，都可能会产生良好效应。其作用机理，尚待进一步研究。

参考文献

[1] 章太戊等：1980。中华理疗杂志，4：193—194。
[2] ———：1982。同上，4：218—219。
[3] ———：1984。同上，4：218—219。
[4] 蒋栋良等：1980。同上，4：195—196。
[5] 汪荫堂：1982。同上，1：48—50。
[6] 张庭仁等：1984。同上，2：92—95。
[7] 季广贤等：1985。同上，1：47—48。
[8] 赵金庆：1981。医学研究通讯，3：23。
[9] 西安医学院卫生学教研室等：1983。劳动卫生与环境医学，6(3)：33—35。
[10] 李安伯：1983。西安医学院学报，4(1)：103—108。
[11] 李安伯等：1984。同上，5(4)：385—389。
[12] 刘凌云等：1985。北京师范大学学报(自然科学版) 3：75—78。
[13] Alper, T.: 1956. *Radiat. Res.*, 5: 573—586.
[14] Brewen, J. G.: 1965. *Int. J. Radiat. Biol.*, 9: 391—397.
[15] Dewey, W. C. and S. M. Robinette: 1969. *ibid.*, 16: 495—500.
[16] Emerit, T. et al.: 1982. *Mutat. Res.*, 103: 165— 172.
[17] Giles, N. H. et al.: 1950. *Genetics*, 38: 416—420.
[18] Hirai, H. et al.: 1982. *Mutat. Res.*, 93: 419—437.
[19] Hsu, T. C. et al.: 1962. *Exp. Cell Res.*, 27: 441—452.
[20] Latt, S. A.: 1974. *Proc. Natl. Acad. Sci.* (USA), 71: 3162—3166.
[21] Proceedings of the 7th Int. Biometeorological Conference, 1975.
[22] Proceedings of the 8th Int. Biometeorological Conference, 1979.
[23] Proceedings of the 9th Int. Biometeorological Conference, 1981.
[24] Scott, D. and H. J. Evans: 1967. *Mutat. Res.*, 4: 579—599.
[25] Shahgholi, M. and Ali-Sekhavat: 1975. *U. S. Patent.* 3910778.

Studies of Air Negative Ion Protection from the Chromosome Aberrations and SCEs Induced by γ-rays in Mice

Guo Xuecong　Liu Lingyun　Liu Yan　Di Shaojie　Fei Qing
(Department of Biology, Beijing Normal University)

Zhou Ruiying　Xie Lin　Guo Yue
(The Institute of Low Energy Nuclear Physics, Beijing Normal University)

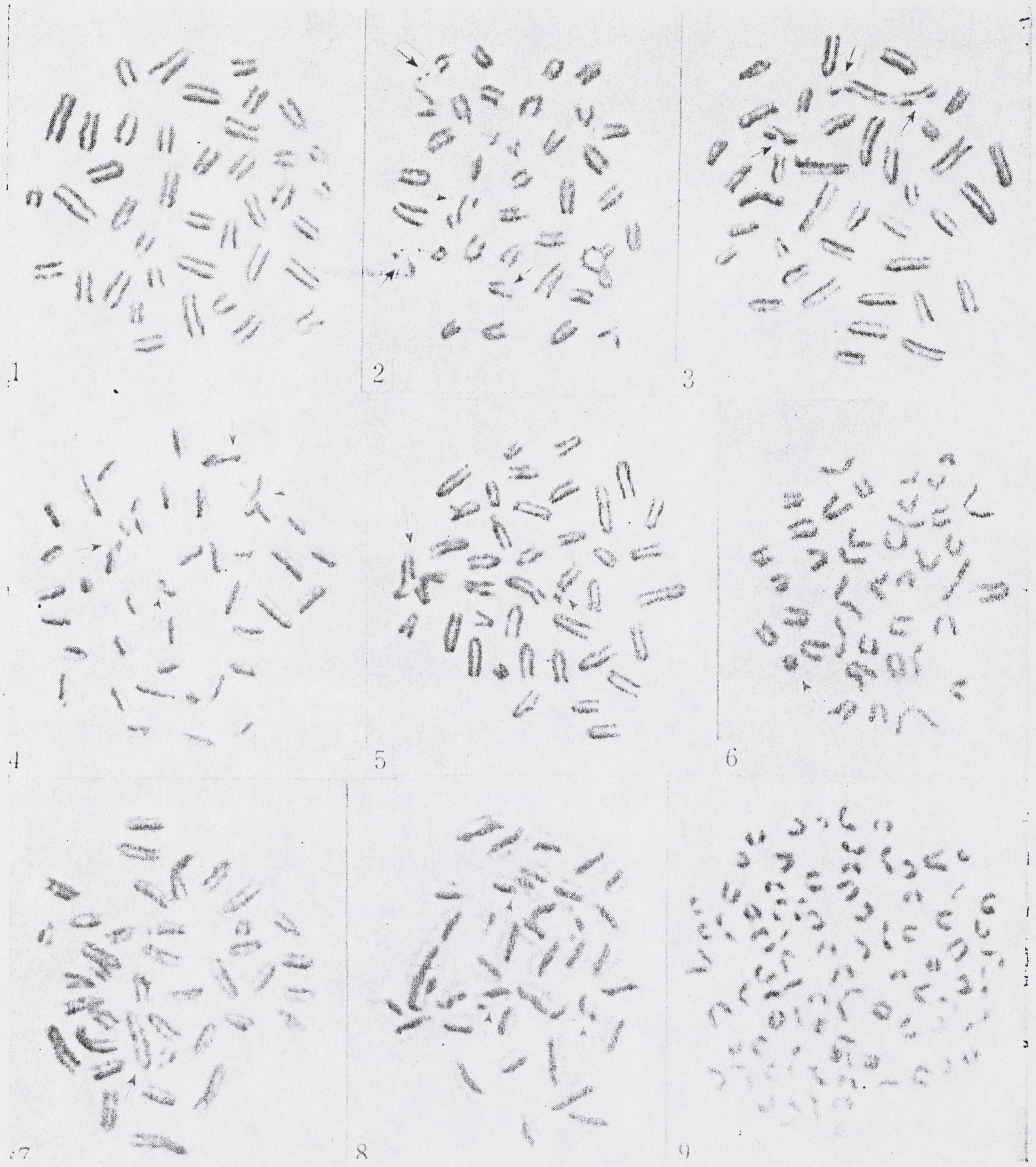
ABSTRACT

In view of the fact that the air negative ions have good effect on medical treatment and health, we consider it rather difficult to study directly about the effect of the air negative ions on the chromosomes and DNA. It has been known that the DNA is an important target molecule of radiation, so this paper presents an exploration through the effect of radiation to see whether the air negative ions would protect the chromosomes and DNA from radiation damage. The Kunming mice were used as the experimental animals (male, average body weight: ca. 12g). According to the same degree of body weight, the 302 mice were divided into six cages at random. These mice were reared in two rooms built in the same style. Three cages of mice were put in one room provided with the air negative ions, while the other three were put in the other room provided with the same amount of the ordinary air as the air negative ions. In doing so 70 days running, these mice were exposed to γ-rays. After radiation they were killed at 2, 4, 8, 12, 16, 20, 24, 36, and 48 h respectively, and their bone marrow cells were used to make the chromosome preparations, then various aberrations and SCEs of chromosomes and chromatids were examined under microscope and statistical analysis was made. The experimental data showed that there is a protective function of air negative ions on the chromosome damage induced by radiation.

Received May 10, 1985.

郭学聪等：空气负离子对γ-射线诱发小鼠染色体畸变和SCE防护作用的研究
图版 I

Guo Xuecong et al.: Studies of Air Negative Ion Protection from the Chromosome Aberrations and SCEs Induced by γ-rays in Mice Plate I



γ-射线诱发小鼠骨髓细胞染色体畸变类型及 SCE 等(箭头所示)：1. 正常分裂相；2. 染色单体断裂、染色单体间隙、微小体等；3. 染色体断裂、染色单体间隙、染色单体断裂；4. 三射体、染色单体断裂、SCE；5. 四射体、染色体间隙；6. 染色体环；7. 双着丝点体；8. 姊妹染色单体交换 (SCE)；9. 四倍体。

Photographs of various chromosome aberrations and SCEs (Arrows indicated) induced by γ-rays in mouse bone marrow cells: 1. Normal mitotic figure; 2. Chromatid breaks, chromatid gap, minutes etc.; 3. Chromosome break, chromatid gap and break; 4. Triradiatus, chromatid break, SCEs; 5. Quadriradiatus, Chromosome gap; 6. Chromosome ring; 7. Dicentric; 8. Sister chromatid exchanges(SCEs); 9. Tetrapoloid.

第8卷 第2期　　环境科学学报　　Vol. 8, No. 2
1988年6月　　ACTA SCIENTIAE CIRCUMSTANTIAE　　June 1988

研究简报

黄鳝染色体体外SCE检测系统的建立及对两种清洗剂的检测

狄少杰*　　刘凌云
（北京师范大学生物系）

关键词：体外SCE检测系统；黄鳝；去污粉；洗衣粉.

姐妹染色单体交换(SCE)技术已在细胞生物学、细胞遗传学、环境毒理学、医学等领域得到了重视和应用. 在检测环境诱变剂和致癌剂方面，SCE比染色体畸变敏感二百倍[1].

关于体外SCE检测系统的研究，除了较多地利用人外周血淋巴细胞和中国仓鼠卵巢(CHO)细胞作为SCE检测材料外[2—5]，也开始利用各种生态环境中的动物. 对鱼类SCE的研究，国外做过一些工作，但有关建立SCE检测系统的报道极少[6—8]. 国内有关鱼类SCE的工作也很少[9—11]，迄今未见建立SCE检测系统的报道. 我们根据黄鳝染色体个较大、数目少($2n=24$)、为端着丝点染色体、便于SCE计数且生活力较强的特点，应用离体培养细胞SCE分析技术，测试黄鳝血淋巴细胞染色体SCE对典型诱变剂的敏感性，建立体外SCE检测系统，并对去污粉、洗衣粉的遗传诱变性进行了初步检测.

材料与方法

黄鳝(*Monopterus albus*)购自北京北太平庄农贸市场，共做了47尾鱼.

离体血淋巴细胞培养及SCE技术，均按刘凌云的方法[9,12]. 实验组分别加入四个不同剂量浓度的诱变剂MMC（日本产，0.005、0.01、0.25、0.5μg/ml）和CP（国产，1.0、1.5、2.0、3.0μg/ml）. 普通去污粉（北京香堂日用化工厂产）和熊猫洗衣粉（北京产）的检测浓度为0.2和0.6μg/ml. 对照组加入0.9% NaCl溶液.

实验结果

1、黄鳝血淋巴细胞染色体SCE敏感性测试

选用两种阳性药物：终致癌剂MMC和前致癌剂CP（未经体外活化）. 共观察统计

国家自然科学基金资助课题.

* 现在北京师范大学低能核物理研究所工作.

890个SCD-2分裂相．结果平均每细胞自发SCE频率为0.527±0.129．不同浓度MMC诱发黄鳝血淋巴细胞SCE频率变化范围为1.18—12.84，比对照组增加了1.24—23.37倍．CP诱发的变化范围为1.84—3.96，比对照组增加了2.50—6.51倍(表1、图1)

表1　MMC、CP体外诱导黄鳝血淋巴细胞SCE频率

Table 1 SCEs frequencies induced by MMC and CP

阳性药物	剂量 (μg/ml)	实验鱼尾数	SCD-2 中期相数	SCES/细胞 ($\bar{x}$ ± SD)	P
对照	0	6	229	0.527±0.129	
MMC	0.005	3	193	1.180±0.067	<0.001
	0.01	3	183	2.468±0.552	<0.001
	0.25	3	185	5.532±1.549	<0.001
	0.5	3	91	12.843±1.114	<0.001
CP	1.0	3	128	1.843±0.016	<0.001
	1.5	4	155	2.306±0.527	<0.001
	2.0	3	114	3.206±0.191	<0.001
	3.0	4	142	3.959±0.543	<0.001

CP(2.0μg/ml)　　MMC(0.5μg/ml)

图1　黄鳝血淋巴细胞中期相

Fig. 1 Lymphocyte metaphases of *M. albus* (arrows showing SCEs)

从表1和图1可见，MMC和CP用药组诱发SCE频率明显地随给药剂量的增加而增加，与对照组SCE频率变化之间有显著性差异($P<0.001$)，显示了诱变剂浓度与诱发SCE频率基本呈线性关系．结果还表明，MMC的体外诱变活性较CP的至少高6倍．MMC在0.25μg/ml浓度时出现较多染色单体断裂、染色体断裂、三射体、四射体等畸变类型．CP在2.0μg/ml浓度时仅出现断裂畸变类型．

2、黄鳝血淋巴细胞染色体SCE对去污粉、洗衣粉诱变作用的检测

洗衣粉的主要成分为十二烷基苯磺酸钠，去污粉的主要成分为白云石粉，还含有碱、钙、铁及洗衣粉等．本实验以黄鳝作为体外SCE检测系统，对其诱变作用进行检测．

表2　去污粉、洗衣粉体外诱导黄鳝血淋巴细胞SCE频率

Table 2　SCEs frequencies induced by a cleaner and a washing powder in vitro in lymphocytes of *M. albus*

处　理	剂　量 (μg/ml)	实验鱼尾数	SCD-2 中期相数	SCE数/cell ($\bar{x} \pm SD$)	SCE数/染色体 ($x \pm SD$)	P
对　照	0	3	94	0.821±0.072	0.035±0.003	
去污粉	0.2	3	91	1.713±0.141	0.071±0.006	<0.01
	0.6	3	92	2.347±0.300	0.098±0.012	<0.01
洗衣粉	0.2	3	96	2.448±0.424	0.102±0.018	<0.01
	0.6	3	94	3.236±0.147	0.135±0.006	<0.01

表2表明，当去污粉、洗衣粉浓度为0.2和0.6μg/ml时，均可明显提高SCE频率，统计学上差异显著($P<0.01$)．去污粉诱发SCE频率是对照的2.1—2.9倍，洗衣粉是对照的3.0—3.9倍，洗衣粉的诱变性是去污粉的1.4倍左右．洗衣粉在0.2μg/ml浓度时即可导致出现染色单体断裂、染色体断裂等畸变现象．

讨　　论

通常将低浓度BUdR产生的SCE视为自发频率．本实验使用的BUdR浓度为8—10μg/ml，基本属于较低浓度．从表1可见，黄鳝血淋巴细胞SCE自发频率为0.527 SCEs/cell，与我们过去所做的离体淋巴细胞SCE自发频率(0.326 SCEs/cell[9])和活体淋巴细胞SCE自发频率(0.541 SCEs/cell)基本一致．将其与同类工作进行比较可见(表3)，黄鳝的自发SCE频率低于人和其它动物组，比白鲢肾细胞和Ameca splenden鱼培养细胞系约低8—9倍．虽然SCE自发频率受诸种理、化、生物因子的影响，各作者使用的检查对象、实验方法、BUdR浓度均不同，但总的来看，本实验得到的黄鳝血淋巴细胞SCE自发频率属于低水平，这是检测环境诱变剂和致癌剂的一个有利指标．

体外SCE实验结果表明，用不同浓度MMC诱发黄鳝血淋巴细胞SCE时，其SCE频率分别比对照组增加1.2、3.7、9.5、23.4倍，CP分别高于对照组的2.5、3.4、5.1、6.5倍(表1)．表明黄鳝血淋巴细胞染色体存在着潜在的遗传敏感性，极易被MMC、CP之类的诱发物诱导产生SCE．与过去同类工作相比，结果基本一致(表4)．由此，可以确认黄鳝比人、哺乳动物及其它动物对典型诱变剂更为敏感，是较理想的鱼类染色体SCE检测系统．

本工作所用的CP未经体外活化处理，同样明显地提高了离体培养的黄鳝血淋巴细胞SCE频率($P<0.001$)．这一现象反映了黄鳝血淋巴细胞可能存在类似动物肝微粒体混合功能氧化酶的代谢活化酶系，使CP活化成为有活性的物质，详细解释，尚需进一步研究．

表3　黄鳝与其它动物体外的SCE自发频率比较

Table 3 Comparison of the spontaneous SCE frequencies between *M*, *albus* and other animals

细　　胞	BUdR剂数(μg/ml)	SCE数/cell($\bar{x}$±SD)	SCE数/染色体	文献编号
人血淋巴细胞	3	5.74±0.42	0.125	13
	5	5.02±0.16	0.11	16
中国地鼠细胞株	7	2.69±1.36	0.146	17
中国仓鼠成纤维细胞	15	6.86±1.05		18
中国仓鼠卵巢细胞	0.077—6.1	7.9—15.2	0.36—0.69	14
家兔血淋巴细胞	6	5.66±2.00		19
白鲢肾细胞	5	4.62±0.32		10
Ameca Splenden 鱼细胞系	4.6	5.07±0.42		15
黄鳝血淋巴细胞	8—10	0.326±0.133	0.014±0.005	9
		0.527±0.129	0.022±0.005	本实验

表4　黄鳝与其它动物体外MMC、CP诱发SCE频率比较

Table 4 Comparison of the SCES frequencies induced by MMC and CP between *M. albus* and other animals

阳性药物	细　　胞	阳性药物剂量(μg/ml)	SCE数/细胞($\bar{x}$±SD)		文献编号
			自　发	诱　发	
MMC	人血淋巴细胞	0.01	4.46±1.19	12.88±3.01	19
		0.05	5.02±0.16	8.5±0.65	16
	家兔血淋巴细胞	0.01	5.66±2.00	23.58±0.86	19
	Ameca Splenden 鱼细胞系	0.03	5.07	43.0	15
	白鲢肾细胞	0.012	4.62	17.60	10
	黄鳝血淋巴细胞	0.01	0.527±0.129	2.468±0.552	本实验
CP	人血淋巴细胞	0.001	5.58±0.44	6.17±0.27	21
		0.001±5—9	5.14±0.37	8.32±0.54	
	中国仓鼠成纤维细胞	26+5—9	13.46	45.72	20
	黄鳝血淋巴细胞	1.0	0.527±0.129	1.843±0.016	本实验

应用本工作所建立的SCE检测系统，检测了日常用的洗衣粉和去污粉，初步证明了二者有较强的诱变作用，在洗涤食品器皿中有潜在的遗传危险性，同时证明了这一检测系统能灵敏地反映染色体DNA损伤修复的程度．该技术简便、快速，是检测环境致癌物的有用工具．

参考文献

〔1〕 Latt S A. *Proc Natl Acad Sci U S*, 1974; 71: 3162
〔2〕 Perry P *et al*. *Nature*, 1975; 258:121
〔3〕 邓承宗等. 遗传学报,1979;6(1):128
〔4〕 刘爱华等. 环境科学学报,1984;4(4):387
〔5〕 James D T *et al*. *Mutat Res*, 1984; 138(1): 93
〔6〕 Kligerman A D *et al*. *Chromosome*, 1976; 56: 101
〔7〕 Kligerman A D. *Mutat Res*, 1979; 64: 205
〔8〕 Vigfusson N V *et al*. *Mutat Res*, 1983; 118:61
〔9〕 刘凌云. 北京师范大学学报(自然科学版),1984;3:85
〔10〕 李康等. 细胞生物学杂志,1983;5(3):26
〔11〕 虞世嘉等. 细胞生物学杂志,1985;7(4):182
〔12〕 刘凌云. 北京师范 学学报(自然科学版),1981;3:79
〔13〕 吴昊等. 实验生物学报,1979;12(11):31
〔14〕 Wolff S *et al*. *Chromosome*, 1974; 43: 341
〔15〕 Barker C T *et al*. *Mutat Res*, 1979; 68: 381
〔16〕 吴玉清等. 细胞生物学杂志,1980;2(2):16
〔17〕 王钡钦等. 环境科学学报,1983;3(1):78
〔18〕 李昌本等. 实验生物学报, 1979;12 (2) :131
〔19〕 崔梅影等. 科学通报, 1981;1 :50
〔20〕 Thust K *et* al.*Mutat Res*, 1978;51:397
〔21〕 赵寿元等. 实验生物学报, 1981;14(2):123

1987年4月7日收到

AN IN VITRO SCE DETECTING SYSTEM OF CHROMOSOMES IN *M. ALBUS* AND ITS USE IN THE ASSAY OF MUTAGENICITY OF DETERGENTS

Di Shaojie, Liu Lingyun

(Department of Biology, Beijing Normal University)

ABSTRACT

The sensitivity of sister chromatid exchanges (SCEs) of blood lymphocytes of *M. albus* was tested with different dosages of mitomycin C (MMC) and cyclophosphamide (CP), using SCE analysis technique. The results showed that the spontaneous frequency of SCEs was quite low (0.527 SCEs/M. P). However, the frequencies of SCEs induced with MMC or CP increased by 1.24 to 23.37 times and 2.50 to 6.51 times respectively, comparing to the control group. The SCEs induced by MMC and CP in *M. albus* were much more sensitive than those in other animals. The technique was used to assay the mutagenicity of detergents and it was found that a cleaner and a washing powder at concentrations of 0.2 to 0.6 μg/ml could cause significant increase in frequency of SCEs.

Keywords: SCE; detecting system; fish; detergent.

Pages 46–56 *in* G. E. Hall and M. J. Van Den Avyle, editors.
Reservoir Fisheries Management: Strategies for the 80's.
Reservoir Committee, Southern Division American Fisheries Society, Bethesda, Maryland. 1986.

ASSESSMENT OF FISH POPULATIONS AND MEASUREMENT OF ANGLER HARVEST

Indices as Predictors of Fish Community Traits

ROBERT F. CARLINE
Ohio Cooperative Fishery Research Unit[1]
The Ohio State University
Columbus, Ohio 43210

ABSTRACT

Objectives of this paper are to review the use of indices as predictors of fish standing crops, yields, and community structure and to outline some alternative approaches to reservoir research. Considerable progress has been made in predicting standing crops and yields in lakes and reservoirs from relatively simple indices. Earlier work relied mostly on abiotic variables, but more recent studies have incorporated biotic parameters into predictive indices. Present models may account for over 90% of the variability in yield or standing crops from a subset of lakes. In contrast, little progress has been made in relating fish community structure to environmental variables. Different ways of describing community structure should be explored. Besides taxonomic groupings, fishes can be grouped by trophic level, by habitat use, and by reproductive mode. Relating community characteristics to environmental variables may be best accomplished by first classifying reservoirs according to major habitat features and then proceeding with analyses of individual classes.

In this paper I review some uses of indices as predictors of fish community traits, specifically standing crops, yields, and community structure, and suggest approaches to reservoir biology that merit further attention. Community is used in the broadest sense throughout the paper to include all game and nongame fish species.

Indices can be labeled descriptive or predictive. Fisheries biologists have long used descriptive indices to characterize various attributes of fish populations. For example, catches of young-of-year (YOY) have been used as indices of recruitment and gonad to body weight ratios have been employed as indices of maturity. Such descriptive indices can be particularly useful when the attribute of interest cannot be easily measured. At the community level, indices have been used to describe species diversity in a variety of ways (Pielou 1977). While such tools have undoubtedly been useful in describing populations or communities, perhaps the most valuable use of indices has been as predictors of community traits, such as standing crops and yields. I use index to denote a simple or transformed variable or a small set of variables expressed as a formula.

Over the past 15 to 20 years considerable progress has been made in predicting fish standing crops and yields from a variety of aquatic habitats. Early attempts at correlating fish standing crops to environmental variables were motivated by the need to predict carrying capacities of proposed reservoirs (Rounsefell 1946). More recently, development of this predictive capability has been fervently pursued, because it provides biologists with a basis for estimating yields and thus formulating management plans. Ideally, indices derived from one or a few readily obtainable measurements would be all that are needed for making predictions about individual systems. Use of readily measured variables is particularly important to reservoir biologists, because the size and complexity of impoundments make intensive assessment surveys expensive.

Development of predictive indices does not require an understanding of how fish communities function nor are large amounts of data essential. Alternatively, reliance on complex mathematical models for predictions requires quantitative descriptions of important biotic and

---

[1] The Unit is jointly sponsored by the U.S. Fish and Wildlife Service, Ohio Department of Natural Resources, and The Ohio State University.

**Table 1. Summary of perc
used to predict fish yield
ables.**

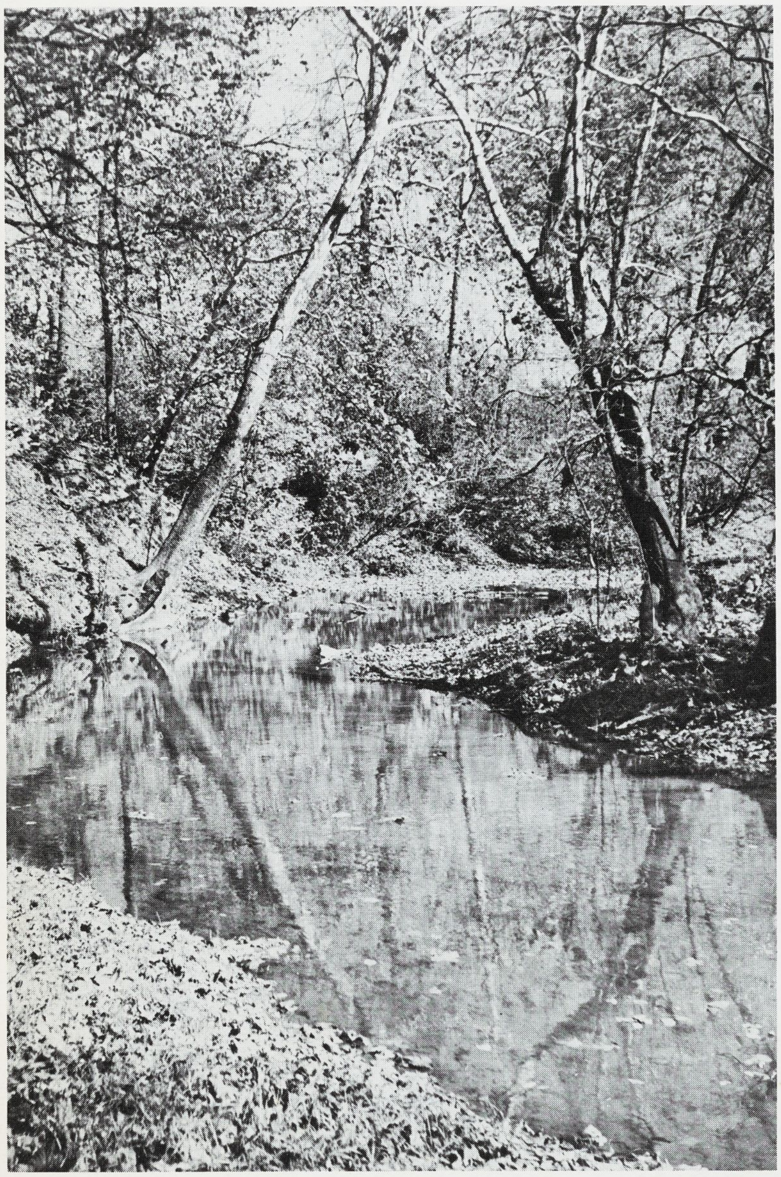
Independent variabl
Mean depth
Mean depth; MEI
Phytoplankton production
Phytoplankton standing crop; phyt
Benthic biomass; MEI
Surface area
Length of growing season
Total phosphorus; TDS; MEI; bent depth
Mean depth; MEI
Mean depth; TDS
Mean depth; TDS
Surface area; mean depth; TDS
Length of growing season; MEI
Surface area; mean depth; TDS; tot biomass
Chlorophyll *a*; total phosphorus
Mean depth; MEI
Length of growing season; surface a
Alkalinity
Benthic biomass ÷ mean depth; me mass
Surface area; mean depth; benthic b mass ÷ mean depth
Length of growing season; surface ar macrophyte abundance; panfish ir
Alkalinity
Retention time
Annual outflow volume; retention ti
MEI
Total phosphorus; Secchi-disc depth
Length of growing season; annual ou line development index; TDS

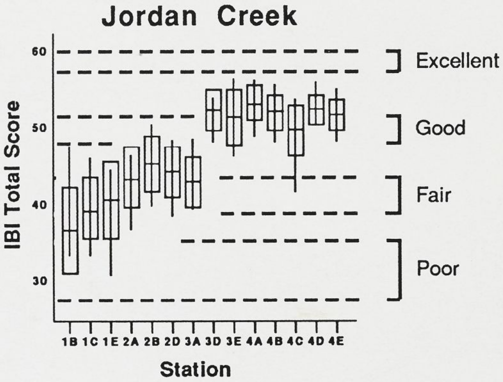
[a] Abbreviated variables are MEI =
[b] S = single-variable model; M = n
variable giving the best predictions i
[c] Some data from lakes were inclu
[d] Some data from reservoirs were

abiotic interactions. While th
ceived a great deal of attent
been successfully managed sc
such models (Walters 1980).
of reservoir dynamics is still
construction of detailed mo
plified models may adequatel

Assessing Biological Integrity in Running Waters A Method and Its Rationale

James R. Karr
Kurt D. Fausch
Paul L. Angermeier
Philip R. Yant
Isaac J. Schlosser





Illinois Natural History Survey
Special Publication 5 September 1986

The Condor 88:35–42

UTILIZATION OF BENTHIC-FEEDING FISH BY INLAND BREEDING BALD EAGLES[1]

Dennis D. Haywood[2] and Robert D. Ohmart
Center for Environmental Studies, Arizona State University, Tempe, Arizona 85287 USA

Abstract. Prey utilization was investigated at 11 Bald Eagle (*Haliaeetus leucocephalus*) nests in Arizona over a five-year period beginning in 1978. Visual observations of prey species delivered to the nest and those found in prey remains were in good agreement. Fish, primarily channel catfish (*Ictalurus punctatus*) and other benthic-feeding fish, composed 77% of the prey items found at the nest. Diurnal timing of capture of fish was not found to vary significantly. Measurement of river-bottom profiles at 22 foraging sites yielded similar physical characteristics. Such characteristics indicate a strong relationship between river-bottom profile and acquisition of benthic-feeding fish by Bald Eagles.

Key words: Bald Eagles; prey utilization; Bald Eagle food habits; southwestern Bald Eagles; Arizona Bald Eagles; channel catfish; carp.

INTRODUCTION

A small breeding population of Bald Eagles (*Haliaeetus leucocephalus*) occurs along the Salt and Verde rivers in central Arizona and their associated tributaries. This population is unique because it occupies the southern extent of the species' range and breeds in a desert riparian environment. Prey utilization by inland breeding Bald Eagles is well documented (Lincer et al. 1979); however, little has been published on prey use by this desert-dwelling population. Our objectives were to determine diet composition, to compare prey use with that from other regions, and to examine foraging behavior to determine what aquatic habitat was used in foraging. This study was conducted in order to provide baseline information needed by agencies to evaluate potential effects of proposed construction of water-storage and flood-control dams on major Arizona waterways.

STUDY AREA

The study area was along the Salt and Verde rivers in Arizona, covering approximately 160 km upstream on each river from the Salt-Verde confluence. General locations of the 11 nest sites studied are presented in Figure 1. The Salt River drains the western White Mountain area and the eastern Mogollon Rim. The Verde River drains the western Mogollon Rim and the central mountains. Several water impoundments occur on these waterways, but no active nest site is known to occur at any of these impoundments. Vegetation of the areas surrounding each nest site is that found in the Lower and Upper Sonoran Life Zones (Lowe 1964).

METHODS

Eleven nests, composing the entire Arizona breeding Bald Eagle population known during the course of this study, were observed from the 1976 breeding season through the 1982 breeding season. Two to three observers were stationed at inconspicuous, yet advantageous, lookout points at each nest site. Radio communications between observers at several nest sites aided in visually tracking the eagles. All flight paths, perches, and foraging sites were drawn on 7.5-min USGS topographic maps. Foraging sites were defined as the precise location where a prey capture, or attempted prey capture, was observed.

Preliminary observations indicated that Bald Eagle pairs were habitually foraging from the same general areas of free-flowing water. In order to examine what characteristics of the aquatic habitat may be important to foraging success, we determined river-bottom profiles for 23 foraging sites by recording substrate, bottom depth, and water level at 1.5-m intervals. Substrate was classified into nine categories as defined by Trihey and Wegner (1981).

From 1978 to 1982, prey remains were collected during banding of young, from adult foraging sites, and from in and around all 11 active nests after all birds had dispersed. Prey was identified from characteristic fur, bones, and body parts. When multiple numbers of body parts of a given species were present at one time and place, the greatest number of the same body part was used to determine the number of prey individuals present. This method was evaluated by comparison with recorded observations of adults returning to the nest with prey. At the time of delivery to the

---

[1] Received 15 September 1984. Final acceptance 9 September 1985.

[2] Present address: Arizona State Game and Fish Department, 2222 W. Greenway Road, Phoenix, Arizona 85023.

Selection of Microhabitat in Summer by Juvenile Atlantic Salmon (*Salmo salar*)

D. L. Morantz, R. K. Sweeney, C. S. Shirvell,[1] and D. A. Longard

Department of Fisheries and Oceans, Fisheries Research Branch, P.O. Box 550, Station "M", Halifax, N.S. B3J 2S7

Morantz, D. L., R. K. Sweeney, C. S. Shirvell, and D. A. Longard. 1987. Selection of microhabitat in summer by juvenile Atlantic salmon (*Salmo salar*). Can. J. Fish. Aquat. Sci. 44: 120–129.

This study was designed to define the microhabitats selected in summer by juvenile Atlantic salmon (*Salmo salar*). Curves were developed describing the preference of 880 young salmon for water velocity at the fish's position (nose velocity), mean water column velocity, total water depth, and stream substrate size. Study sites were chosen in six morphologically diverse streams in Nova Scotia and New Brunswick during 1982–84. Of the four variables measured, only nose velocity chosen by both fry and parr was not significantly different among years or rivers. Atlantic salmon fry (<65 mm) most frequently selected nose velocities between 5 and 15 $cm \cdot s^{-1}$, small parr (65–100 mm) between 5 and 25 $cm \cdot s^{-1}$, and large parr (>100 mm) between 5 and 35 $cm \cdot s^{-1}$. Apparently, juvenile salmon utilized water depths and stream substrates which varied within tolerable limits according to their availability in conjunction with preferred water velocities. Significant differences in the body shape and size of the pectoral fin of Atlantic salmon parr in different rivers did not influence the selection of nose velocities within the range of flow conditions sampled.

Cette étude avait pour objectif la définition des microhabitats choisis l'été par les jeunes saumons atlantiques (*Salmo salar*). Des courbes de préférence en fonction de la vitesse de l'eau à la position du poisson (vitesse devant le nez), de la vitesse moyenne de la colonne d'eau, de la profondeur totale et de la granulométrie du substrat, ont été calculées avec 880 saumons. Les stations ont été choisies dans six cours d'eau à la morphologie différente, en Nouvelle-Écosse et au Nouveau-Brunswick, en 1982–1984. Des quartre variables mesurées, seule la vitesse de l'eau devant le nez choisie par le fretin et les tacons ne marquait pas de différence significative d'une année à l'autre ou d'une rivière à l'autre. Le fretin (<65 mm) choisissait le plus souvent des vitesses comprises entre 5 et 15 $cm \cdot s^{-1}$, les petits tacons (65–100 mm), entre 5 et 25 $cm \cdot s^{-1}$ et les gros tacons (>100 mm), entre 5 et 35 $cm \cdot s^{-1}$. Apparemment, les jeunes saumons choisissaient des profondeurs d'eau et des substrats qui variaient à l'intérieur de limites tolérables, selon la disponibilité et en fonction de la vitesse d'écoulement de l'eau préférée par les saumons. Les différences significatives de morphologie et de taille de la nageoire pectorale chez les tacons de différentes rivières n'ont eu aucun effet sur le choix de la vitesse de l'eau au bout du nez à l'intérieur de la plage des conditions d'écoulement échantillonnée.

Received January 22, 1986
Accepted August 17, 1986
(J8658)

Reçu le 22 janvier 1986
Accepté le 17 août 1986

Stream discharge, particularly during the spring and summer, can substantially influence the size of Atlantic salmon (*Salmo salar*) parr populations (Frenette et al. 1984), possibly by determining a stream's depth and velocity. Water depth, water velocity, cover, and stream substrate have been shown to limit standing stocks of some warmwater fish species (Orth and Maughan 1982) and to correlate with the abundance or biomass of trout (Lewis 1969; Binns and Eiserman 1979; Stalnaker 1979). Although descriptions of juvenile Atlantic salmon habitat requirements are abundant in the literature (Saunders and Gee 1964; Elson 1967; Gibson 1978; Symons and Heland 1978; Rimmer et al. 1984), only Shirvell and Morantz (1983) and Trial and Stanley (1984) have published habitat suitability curves for this species. It is unclear from this existing information whether or not juvenile Atlantic salmon consistently choose similar microhabitats among different rivers. This determination is vital to the protection and management of salmon habitat because physical stream characteristics important to the successful rearing of young salmon must be appropriate to the population in a particular river.

In recent years, the recognition of fish habitat preferences has led to the development of habitat simulation models, particularly the "instream flow incremental methodology" (IFIM) (Bovee 1982), designed to quantify available habitat for given species of fish. The use of IFIM requires that water velocities, water depths, and stream substrates (or cover) used by a species be quantified into habitat suitability curves. The use of such curves may be valid only if they are developed from the study stream itself unless it has been demonstrated that existing curves are appropriate due to the "universality" of microhabitat selection by the species in question. The consistency of habitat selection by brown trout (*Salmo trutta*) among six streams led Shirvell and Dungey (1983) to infer that these fish choose similar habitats in all rivers. Conversely, Atlantic salmon juveniles occupied different habitats between two Maine streams (Trial and Stanley 1984), apparently because of different hab-

---

[1] Present address: Department of Fisheries and Oceans, Fisheries Research Branch, 417 2nd Avenue West, Prince Rupert, B.C. V8J 1G8.

MICROHABITAT USE IN A MEDITERRANEAN RIVERINE FISH ASSEMBLAGE: I

FISHES OF THE LOWER MATARRAÑA

GARY D. GROSSMAN[1]
ADOLFO DE SOSTOA[2]
MARY C. FREEMAN[1]
JAVIER LOBÓN-CERVIÁ[3]

RUNNING HEAD: MICROHABITAT USE IN MATARRAÑA FISHES I

[1*] SCHOOL OF FOREST RESOURCES
UNIVERSITY OF GEORGIA
ATHENS, GA 30602 USA

[2] DEPARTAMENTO DE ZOOLOGIA (VERTEBRADOS)
FACULTAD DE BIOLOGÍA
UNIVERSIDAD DE BARCELONA
BARCELONA, 08071, SPAIN

[3] MUSEO NACIONAL DE CIENCIAS NATURALES
JOSÉ GUTIERREZ ABASCAL, 2
MADRID 28006 SPAIN

[*] Address to which proofs should be sent.

Oecologia: in press

[v.73(4): pp 490-500, 1987]

MICROHABITAT USE IN A MEDITERRANEAN RIVERINE FISH ASSEMBLAGE: II

FISHES OF THE UPPER MATARRAÑA

GARY D. GROSSMAN[1]
ADOLFO DE SOSTOA[2]
MARY C. FREEMAN[1]
JAVIER LOBÓN-CERVIÁ[3]

RUNNING HEAD: MICROHABITAT USE IN MATARRAÑA FISHES II

[1]* SCHOOL OF FOREST RESOURCES
UNIVERSITY OF GEORGIA
ATHENS, GA 30602 USA

[2] DEPARTAMENTO DE ZOOLOGIA (VERTEBRADOS)
FACULTAD DE BIOLOGÍA
UNIVERSIDAD DE BARCELONA
BARCELONA, 08071, SPAIN

[3] MUSEO NACIONAL DE CIENCIAS NATURALES
JOSÉ GUTIERREZ ABASCAL, 2
MADRID 28006 SPAIN

*address to which proofs should be sent

Oecologia

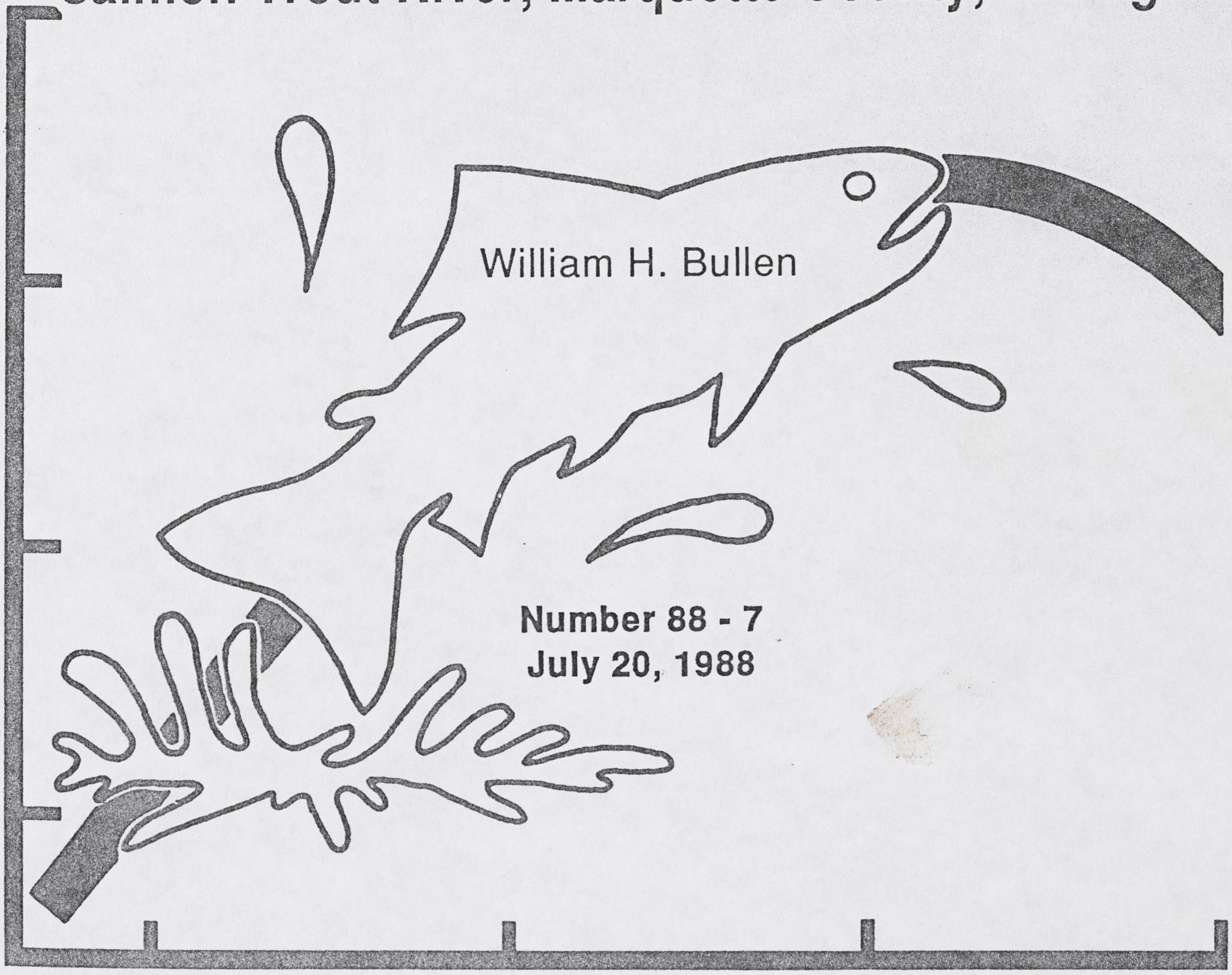
[v. 73 (4): pp 501-512, 1987]

88-7 AH-GENETICS

FISHERIES DIVISION

TECHNICAL REPORT

Fisheries Management Plan for the Salmon Trout River, Marquette County, Michigan



William H. Bullen

Number 88 - 7
July 20, 1988

Michigan Department of
Natural Resources

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Fisheries Technical Report No. 88-7

July 20, 1988

FISHERIES MANAGEMENT PLAN FOR THE SALMON TROUT RIVER, MARQUETTE COUNTY, MICHIGAN

William H. Bullen

INTRODUCTION

Historically, the Salmon Trout River has been best known for its coaster brook trout (*Salvelinus fontinalis*). However, in the past 20 years numbers of these large lake-run brook trout have declined. There is now considerable interest in developing a management plan to increase the abundance of these trophy fish.

This report describes the Salmon Trout River, its past and present fish populations, the related sport fishery, and the coaster brook trout itself. Also discussed are reasons why the Salmon Trout has been, and can continue to be, an excellent coaster stream and factors which may have caused the long-term decline in brook trout abundance. Finally, several specific recommendations are listed for management of the coaster population in this river and nearby coastal waters of Lake Superior.

Because of the private ownership of most of this watershed, minimal physical and biological data have been collected by state biologists. Thus, some sections of this plan are brief and lacking in detail. Fortunately, the Huron Mountain Club has employed several consultant biologists during the past 50 years. Their recorded data form the basis of this plan. Other information on volume of flow, water temperatures, and angler catches have been collected by foresighted club members. Additional data on stream flows and water chemistries were obtained from the U. S. Department of the Interior, Fish and Wildlife Service, Marquette Biological Station (Sea Lamprey Control). Finally, a public meeting was held in Marquette to obtain the benefits of opinions and experiences of anglers who had fished for coasters for many years.

ENVIRONMENT

The Salmon Trout River, a tributary of Lake Superior, is located in northwestern Marquette County approximately 30 miles north and west of the City of Marquette, Michigan. Except for the uppermost reaches, the mainstream and most tributaries lie within the boundaries of the Huron Mountain Club, a privately owned and exclusive organization managed primarily to provide outdoor recreation for its members.

The Huron Mountain area consists of a series of high hills and granite outcroppings. Soils in the lower watershed are relatively thin but stable because of the forest cover. The upper watershed grades from flat to rolling terrain of predominantly sandy soils.

Most of the lands within the club boundaries and in the Salmon Trout watershed are heavily forested, many with virgin timber. Northern hardwoods, hemlock, and red and white pine are common in upland areas. Lowlands are covered with a wide variety of woody vegetation including white birch, white cedar, balsam fir, spruce, tamarack, and tag alder.

Extensive timber harvest has occurred, and is continuing, in the upper watershed outside of the club boundaries.

The stream begins about 10 miles south of Lake Superior in an area known as the Yellow Dog Plains. The two main branches (east and west) flow northerly for approximately 7 stream miles before joining and forming the mainstream. The upper portions of these branches flow first through relatively flat, then rolling terrain, until entering the Huron Mountain Club lands. Upon reaching Sections 15 and 16 of T51N, R28W, the branches and mainstream begin dropping rapidly, falling over 300 feet in the last 14 river miles. Most of this rapid decent (260 feet) occurs between the club boundary on the West Branch and the lower falls, a distance of approximately 7 river miles. There are several major falls and two dams within this stretch. The upper falls (T51N, R28W, Sec. 15) is on the West Branch about 0.5 mile above the junction with the East Branch. The middle falls (T51N, R28W, Sec. 14) is approximately 1 mile downstream from the junction of the two branches, and the lower falls (T51N, R28W, Sec. 13) is about 2 miles below the middle falls. Sheet Rock Falls is approximately 300 feet upstream from the lower falls. The upper dam (T51N, R28W, Sec. 15) is almost immediately below the junction of the west and east branches. The lower dam (T51N, R28W, Sec. 13) is approximately halfway between the middle and lower falls. A flat area between the middle and lower falls is known as The Meadows.

The lower falls is the first permanent barrier encountered by fish migrating upstream from Lake Superior. Under certain flow conditions brook trout and other salmonids have been observed ascending this falls. However, within approximately 300 feet the Sheet Rock Falls is encountered, which effectively blocks all further upstream fish movement.

Finally, the river flows a distance of almost 9 miles from the lower falls to Lake Superior. Most of the stretch is characterized by moderate velocities and increased meandering of the stream channel. The lowermost stretch (1.5 miles) flows slowly through tag alder marsh flats before entering Lake Superior.

Little information has been recorded about the east and west branches. These branches, and their many small feeder streams, originate at the base of a moraine which separates this drainage from the Yellow Dog system, located to the south and east. The base flows, even in midsummer, appear stable. The water is colorless and slightly alkaline. The pH of the main branches and selected feeder streams ranges between 7.4 and 7.8. Methyl-orange alkalinity of the West Branch on September 19, 1985, was 58 mg/L.

Clear and Snake creeks are clear spring feeders joining the Salmon Trout mainstream just above the lower dam. Both have stable flows and contribute significantly to the mainstream flow. No records of flow measurements exist.

Only four tributaries enter the mainstream below the lower falls. Their characteristics are noticeably different from those found in upstream waters. Spring Creek, a small, short seepage tributary is almost dry in summer months. A flow volume of 0.5 cfs was recorded on May 17, 1983. This water is more alkaline than that in other tributaries (pH 7.7–8.1, total alkalinity 85–92 mg/L). Murphy Creek enters the mainstream from the east about 1 mile above County Road 550. It too becomes dry in summer and flows only after snowmelt or rainfall. Recorded pH and alkalinity values have a range of 6.8–7.2 and 12–92 mg/L, respectively. Measured flows in Conway Creek have varied from 3.0 to 5.5 cfs in May and June but decline later in the summer. This water is stained and slightly acid (pH 6.2–6.5, alkalinity 16–25 mg/L). Sullivan Creek is very similar to Conway Creek with low summer flows, a stained color, and slightly acid water. None of these lower river tributaries provide significant spawning habitat or other productive environments for anadromous fish.

Water temperatures in the Salmon Trout mainstream seldom rise above 70 °F at County Road 550 Bridge. In fact, during most years when temperatures were consistently recorded (1971–1975) the water rarely exceeded 65 °F. Daily temperature fluctuations vary seasonally and usually are within 3–7 °F but range with occasional differences up to 10 °F. Although not recorded, winter temperatures are undoubtedly warmer than in most other area streams due to the same considerable groundwater seepage in the upper watershed that keeps the water cool in summer months. These temperatures make the river system well suited for brook trout production. The surrounding mature forest, relatively undisturbed watershed, and extensive headwater spring seepage are significant factors in maintaining this vital stability not often found in Lake Superior tributaries.

Water chemistry of the mainstream is reflective of its tributaries. It is a slightly alkaline stream with May-September (1959–1985) pH values ranging from 7.5 to 7.8 at County Road 550. Total alkalinity readings were between 44 and 70 mg/L. Measurements taken at the lower dam on the same days were within these same ranges. Similar values (pH 7.0–8.2 and total alkalinities 28–77 mg/L) were recorded in 1938–1939 (Smith 1942).

The steep terrain and relatively thin soil layer covering the extensive rock substrate in the lower portion of the watershed cause rapid runoff from rainfall and snowmelt. In addition to the high mainstream flows experienced each spring, severe floods have been common even in midsummer months as the result of heavy rains. Summer floods occurred at least in 1937, 1938, 1939, 1949, 1959, 1969, and 1974. These floods caused a rise in water level of 7 to 10 feet at County Road 550 Bridge. Records kept during 1973–1975 for the same location indicate spring runoff flows typically peak over short periods of time (5–10 days) at heights of 4–5 feet above normal. Excluding these seasonal extremes and the major summer floods, the mainstream flow remains relatively stable. Short-term rises in the stream level of 1 foot or more are not uncommon following rainfall but rarely is the flow less than 35 cfs with a water depth of 1.3 feet at County Road 550 Bridge. Flow measurements taken on the same days upstream at the lower dam were similar, indicating minimal input from lower tributaries and groundwater seepage in this stretch. These physical differences in the upper and lower portions of the river (divided approximately at the lower dam) are significant to the production of brook trout.

Streambed soils vary considerably through the length of the stream. The headwaters flow mostly over sand and small gravel until the area of steeper gradient is reached. Exposed bedrock and rock rubble then become common until the Meadows is reached where sand and silt prevail. Below the lower dam ledge, rock, rock rubble, and sand are prevalent. Between the lower falls and County Road 550, sand bed load exists downstream to the vicinity of Sullivan Creek. The remaining streambed is firm sand covered with silt. Sand and small gravel predominate in the feeder creeks.

Instream cover also varies considerably by area. Small pools, rock ledges, and overhanging streambank vegetation are fairly common in the reaches above the lower dam. Below the lower falls, large pools on the many river bends provide fish cover. Log jams exist in some pools but instream log cover between pools is rare. Below County Road 550, sand has filled many pools and cover is limited to undercut banks, stream-side vegetation, and occasional logs. The lower 2 miles of stream provide deeper, slower water, and larger pools.

FISH POPULATION

Smith (1942) identified 31 species of fish in the Salmon Trout River. Brook trout and rainbow trout (*Salmo gairdneri*), northern pike (*Esox lucius*), and burbot (*Lota lota*) were the only predatory species listed. Pike and burbot were found only in the deeper waters of the lower river below the Harrison Pool, located approximately 3 miles upstream from the mouth. All species maintained their abundance through natural reproduction although some brook trout were planted annually to improve midsummer angling success.

A significant coaster migration occurred in late summer in the 1930's but was reported by Smith (1942) as "greatly diminished, apparently in response to the thinning of the population in Lake Superior".

More recent fish surveys in 1966, 1973, and 1983 found brown trout (*Salmo trutta*) and coho salmon (*Oncorhynchus kisutch*) also present downstream from the lower falls. The coho salmon were successfully reproducing in 1975, but no young brown trout were captured.

In 1983, juvenile steelhead (*Salmo gairdneri*) were apparently the most abundant salmonid in the lower river (Diana 1983). In October, Diana collected approximately 550 steelhead (4–5 inches) while capturing only 41 brook trout of all sizes. His sampling occurred at several locations above and below County Road 550. A survey by the Michigan Department of Natural Resources (MDNR) on October 13, 1966, 1.5 miles above County Road 550 captured a more even distribution of 34 brook trout (3–7 inches) and 33 steelhead in the same size range.

The salmonid population in the lower Salmon Trout River has changed significantly in the past 45 years. Brook trout and rainbow trout dominated prior to 1960 with little, if any, competition from other species. Both of these fish are anadromous, living most of their life in Lake Superior and returning to the river only to spawn. In the 1980's coaster brook trout numbers have declined significantly while rainbow trout (steelhead) have at least maintained and perhaps increased their abundance. In some years young rainbow trout may outnumber brook trout by at least 10 to 1. Fall spawning species (brook and brown trout and coho salmon and chinook salmon (*Oncorhynchus tshawytscha*) have increased considerably in the lower river. Young coho salmon also numerically exceed brook trout in some years although reproduction of this species seems highly variable. No records exist to indicate whether total fingerling production has changed since 1940.

Brook trout typically spawn in small tributary streams in areas of significant groundwater upwellings. Egg incubation, hatching, and fry survival are all enhanced by the warmer groundwater during the winter months. Additionally, these smaller spawning streams provide excellent rearing habitat for young trout. The lower Salmon Trout mainstream contains few groundwater seepage areas and very little small fish habitat. The periodic floods also produce a hostile environment for young trout, particularly early spring-hatched brook trout. As a result, it is not likely the lower river ever produced large numbers of brook trout fingerlings even prior to the increased competition and habitat degradation.

No fish population surveys have been completed on the east and west branches above the club boundaries. Anglers report, however, that brook trout are abundant but small (catch size range 4–9 inches) in the many headwater creeks. Clear and Snake creeks are also reported to be excellent producers of small brook trout.

Between 1910 and 1983 the planting of brook trout represented a major investment by the Huron Mountain Club. Fry and fingerling trout (0.5–4.0 inches) were planted prior to 1921 but most subsequent plants have been yearlings (5–7 inches) or adults (8–9 inches). The number of fish planted annually by the club varied considerably but has ranged from 750 to 1,000 adult trout in recent years. The State of Michigan planted brook trout in the headwater areas above the club boundary from 1935 to 1948. Again, sizes and numbers varied from 50 adults in 1948 to 2,000 fall fingerlings in several years. While it is possible some of these planted fish eventually moved down to Lake Superior, their low numbers make it doubtful they made any significant contribution to the overall spawning run of coasters.

Although no recent surveys have been completed, it is believed that brook trout are the only game fish species found above the lower falls. Angler interviews and personal observations above the club boundary support this belief. The headwater streams provide good habitat for brook trout.

THE COASTER FISHERY

Opinions on just when coaster fishing was considered "good" vary considerably with the age and fishing experience of the angler. Smith (1942) reported runs were declining in the 1930's. More recent comments, however, indicate success was best in the early to mid-1950's. Many correlate a decline in the mid-1960's with the introduction of salmon to Lake Superior, yet the 1969 run was described as "one of the finest seasons recorded." Others say the real decline occurred in the early 1970's. Regardless of exactly when fishing was good, anglers agree fishing success in the 1980's is considerably poorer than at any time in their memories.

The major problem in determining the extent of the decline is the lack of consistent catch or survey records. Fortunately, the Huron Mountain Club maintained member catch records during certain years and they provide some insight to variations in coaster abundance. Smith (1942) also provides data for the years 1938–1940 on the total brook trout catch. Since the catch was separated by week, the number of brook trout most likely to have been coasters can be estimated. Smith (1942) states, "With the advance of the season, the peak of fishing intensity on the river shifted from the lower dam pond to the sector below Murphy's. This change is due in part to the desire of the fishermen to try for the lake-run brook trout which start up the river during the first week of August." If one estimates that 50% (an arbitrary number) of all brook trout caught between August 14 and Labor Day of each year by club members were coasters, then some indication of relative abundance can be gained. The above method results in an estimate that 270, 384, and 147 coasters were caught annually by club members in the years 1938–1940. The 3-year average of 267 may be high or low depending on the accuracy of the 50% coaster assumption. Additional coasters were also taken by non-club anglers fishing the lowermost river area and the near-shore waters of Lake Superior.

Prior to 1969, the trout fishing season on Michigan streams closed on Labor Day. Since then trout fishing has been permitted through September 30 on all streams and longer on selected coastal streams. Because the greatest concentration of spawning coasters in the Salmon Trout occurs in September, many anglers believe the harvest allowed by the later closure is responsible for the decline seen in the club members' catch since 1973.

Club members' catch records identified the actual coaster catch in 1969. They noted, "one of the finest seasons recorded." It also was the first year of the extended statewide trout season. As of September 7, 1969, the recorded coaster catch was 84, and the total catch through September 30 was 125.

Club records for the years 1970–1983 depict an abrupt decline in catch from 81 coasters in 1970 to 5 in 1974 but a mild recovery to 24 in 1975. Subsequent records show a relatively stable annual catch of 14–30 fish.

Although the above numbers reflect the catch by members of the Huron Mountain Club, which could vary for several reasons, they are the best data available. They also coincide with angler observations of coaster declines in the Salmon Trout River since at least 1938. If used as future goals, they should be remembered as only partial catches. Non-club anglers also fished portions of this stream and their catch is totally unknown, although by some estimates, it was as high as four times the club members' catch.

Many anglers relate coaster fishing with streams, however, conversations with longtime coaster fishermen indicate some of the best success was experienced in late spring among the large rocks or boulders scattered along the Lake Superior shoreline. Coasters apparently prefer this type of cover in shoal waters which is common near the mouth of the Salmon Trout River.

Fishing success reportedly declined in the shoal habitat in late June and July but improved again in August as the coasters congregated closer to the river mouth prior to spawning. These large brook trout were considered easy to catch both in the near-shore areas and in the river. The main factors limiting the spring and summer fishery were the unpredictable Lake Superior weather and the unprotected boating distance from Big Bay.

Since all adjacent uplands to the lower Salmon Trout River are owned by the Huron Mountain Club, public access to the stream fishery is very limited. Legal access to the lowermost portion is available via the river mouth by boat from Lake Superior. This area is most attractive to anglers in August when coasters first enter the stream and hold in the slower, deeper water. This boat fishery is restricted to approximately 1 mile of stream just above the mouth. Fishing success in past years has been reported as "good" with most anglers catching one or more coasters per trip.

Much of the remaining lower Salmon Trout River is not legally accessible to the public. County Road 550 Bridge is used as a legal public access point but only by wading anglers remaining in the stream. A legal opinion on the status of this road crossing as access should be obtained. Violations of the trespass law are enforced by police officers employed by the Huron Mountain Club. Angler trespass across club lands continues but has reportedly declined in recent years.

The traditional coaster fishery moved upstream into the shallow, gravel spawning areas above County Road 550 as the fall season progressed. Fly fishing for these large brook trout was common and most fish caught by club members were released.

Coasters as large as 5–6 pounds have been reported but most fish are in the 1.5–3.0 pound range (15–20 inches). The largest brook trout caught in recent fall surveys was 20.0 inches long.

COASTER BROOK TROUT LIFE HISTORY

Little has been written about coaster brook trout in Michigan. The following summarizes what is generally known or believed about coasters. This information was obtained from discussions with longtime coaster fishermen, and management biologists, and from MDNR district files, research reports, and personal observations.

Coaster brook trout spawn in the stream. Juveniles rear for sometime in the stream before migrating downstream to the lake. Manion (1977) recorded a significant downstream movement of brook trout in the Big Garlic River, Marquette, County, Michigan. A sea lamprey (*Petromyzon marinus*) trap operated over a 12-year period captured 2,896 brook trout that were moving downstream. Fifty-seven percent were caught during September through November and 25% during May and June. Once in the lake, coasters seem to remain in the vicinity of the parent stream. They apparently retain some homing instinct as do most salmonids and only have to travel short distances when returning to spawn. Fish surveys of near-shore Great Lakes waters usually produce the highest catch regardless of season.

Two major hypotheses exist as to the mechanisms which cause juvenile trout to migrate to the lake. Many anglers and some biologists believe the coaster brook trout is a distinct strain or stock. The difference between coasters and stream brook trout is perceived to be similar to the difference between Great Lakes steelhead and rainbow trout. One strain of each species migrates to the Great Lakes and returns only to spawn while the other remains non-migratory. The observation that some Great Lakes tributaries receive much larger runs of coasters than other nearby streams is viewed as circumstantial evidence that some streams contain genetically distinct coasters while others hold non-migratory brook trout. A migratory strain in the Salmon Trout River would necessarily spawn downstream of the lower falls.

Alternatively, coaster brook trout may be the result of natural reproduction or the stocking of young trout producing an instream population which exceeds the carrying capacity of the stream. Low, midsummer flows limit the amount of habitat by decreasing the stream depth and pool area. Young brook trout are forced downstream to find larger habitat (growing room) and end up in one of the Great Lakes. Seasonal floods may also force young trout into downstream areas because of insufficient local cover which would provide adequate shelter during high flows. If these conditions occur annually, consistent coaster runs would result. Thus, the best coaster streams would be those which have the best conditions for natural reproduction, a limited amount of cover to hold older (larger) trout, and highly fluctuating flows. Fall rains would reestablish suitable flows and permit the larger and older brook trout to enter the stream for spawning. This scenario is feasible for the historically good Upper Peninsula coaster streams, as these share the following characteristics:

(1) Extensive natural reproduction of brook trout. Included is the necessity of clean gravel of suitable size for spawning, considerable groundwater seepage, and minimal competition from other salmonids. Small, stable feeder streams offering preferred spawning habitat are often present.
(2) Limited amounts of habitat for larger trout.
(3) Floods and widely fluctuating flows are common.
(4) Access to the Great Lakes, where offshore waters provide preferred habitat.

At this time, sufficient information does not exist to distinguish between the above hypotheses for Great Lakes coasters. Wilder (1952) studied migratory (sea trout) and non-migratory brook trout in the Moser River System in Nova Scotia to determine if differences in coloration, relative size of body parts, meristic counts, weight-length relationships, age and growth, or resistance to seawater could be used to distinguish one group of fish from the other. He concluded that no evidence was obtained that indicated sea trout and freshwater trout from the Moser River System differed hereditarily. Smith (1958) recorded movement of tagged brook trout in Ellerslie Brook, Prince Edward Island, during the years 1946–1952. A 4-year average of only 16.6% of 3,580 stream-tagged brook trout actually moved downstream into saltwater. As one conclusion Smith states, "Data obtained at Ellerslie Brook, as well as those reported by other investigators, notably Wilder (1952), argue in support of a contention that movements of brook trout from fresh to salt water are basically no more than meeting the requirements of trout, with growth, for larger and more suitable living quarters...there appears no need to postulate races of brook trout with heritable differences to explain their seaward movements and occurrences in salt water."

Age-growth studies on coasters caught in 1982 in Lake Superior found age-1 fish averaging 4.0 inches in total length. Age-2, 7.3 inches; age-3, 11.5 inches; age-4, 14.4 inches; and age-5, 18.3 inches. Few coasters live past age 5 which is also typical of rainbow and brown trout found in Great Lakes waters. Most mature coasters found in a fall spawning run are ages 4 and 5.

DISCUSSION

Coaster brook trout have not been studied extensively anywhere in Michigan. The following discussion is based on the observations of biologists, fishermen, and members of the Huron Mountain Club.

Future progress in understanding the biology of coasters hinges on answering the critical question of whether juvenile coasters migrate lakeward due to genetic programming or to limits in available stream habitat. Answering this would indicate whether coasters were produced in the river above or below the barrier falls, what were the most probable causes of their decline, and what would be the most productive restoration strategies to employ.

The stocking of relatively large numbers of young brook trout into tributary streams with highly fluctuating flows and minimal holding or protective habitat has sometimes been coincident with subsequent increases in coaster populations. As mentioned earlier the Salmon Trout coaster run in 1969 was reportedly much larger than had been seen since the mid-1950's. Later runs again became smaller. This temporary change in a long-term trend was believed to be the result of the Department of Natural Resources planting 25,000 yearling brook trout in 1967 and another 10,000 in 1968 in nearby Marquette Bay. Following the limited-habitat hypothesis, stream conditions may have forced the young hatchery trout downstream to the lake. If conditions for natural reproduction were poor, the newly established run of coasters soon disappeared unless annual plants continued. This same phenomenon has been observed in Lake Michigan tributaries with brown trout. They disappear shortly after being planted in certain streams but reappear, when mature, as large, lake-run fish in the fall. This evidence supports the above hypothesis, but is far from conclusive, as: (1) a relationship between stocking and coaster abundance has not been clearly documented and (2) if it were, the fact that stocked fish move into Lake Superior and survive does not permit the conclusion that the same phenomenon occurs in wild populations.

Almost every angler has a strong personal opinion as to the cause of the decline in the coaster run in the Salmon Trout River. Commercial fishing, lamprey predation, poaching, extended trout season, salmon, steelhead, beavers, poor reproduction, sand, no planting, and acid rain are among the reasons voiced. In all likelihood, none is solely responsible yet few are totally blameless. The coaster decline is probably the result of several factors impacting over a period of many years, not one or two catastrophic events.

Because of its life history, a coaster brook trout population could decline as a result of problems in either the stream environment or the Great Lakes environment or both. Each should be examined separately.

The environment of the Salmon Trout River system has been responsible for making it what many consider the best coaster stream in Michigan. It has been a very productive brook trout system with stable flows, excellent spring-fed tributaries, and almost ideal water temperatures. Natural reproduction has been consistently good. The lower portion of this watershed has remained relatively unchanged by man's influence due to its preservation by the Huron Mountain Club. In that respect it is unique among Michigan's trout streams. The sport fishery on the river has been controlled. Steelhead and salmon are denied access to most of the stream. But the Salmon Trout River has changed over the years. In several river areas a duned, sand bed load indicates excessive and detrimental downstream movement of sand. This sand movement appears to have increased significantly in recent years as evidenced by the obvious front edge of the dune seen below County Road 550 in the lower river. Some of this sand apparently comes from eroding stream banks above County Road 550, but much sand is also evident in the upper reaches of the east and west branches and their tributaries. The most obvious sources in this area are the many logging roads and trails which erode severely with each snowmelt and rainfall. Washed-out culverts, fords, and flow diversions across roads by beaver dams are allowing tons of sand to enter these once productive headwater feeder creeks. Only recently have detailed studies by Michigan research biologists proven and quantified the highly damaging effects of such sand movement.

Recently beaver populations have increased dramatically in stream systems throughout the Upper Peninsula. The Salmon Trout has been similarly impacted. A new beaver dam now extends across the mainstream above Murphy Creek. Other dams block upstream migration into Spring Creek, Clear Creek, and Snake Creek. Many dams in upper river areas and tributaries outside the club boundaries interfere with fish movement, spawning, and stream productivity.

Competition from young coho and possibly chinook and pink salmon has existed at least during some years since 1966. Young steelhead continue to be very numerous in the lower river. This situation is not unique to the Salmon Trout River nor are the probable results. Based on observed changes in brook trout populations in other Lake Superior tributaries, it is very likely that mainstream production of young brook trout is significantly less now than it was before 1970.

Periodic chemical treatments in the lower river for sea lamprey larvae may have stressed the resident fish population to some degree. The first chemical treatment to kill lamprey larvae was completed in September 1959. Subsequent treatments downstream from the lower dam occurred in 1963, 1971, 1975, 1978, 1983, and 1985. The Salmon Trout River is considered a moderate to heavy producer of sea lampreys and must be routinely treated to minimize the number of these parasites leaving the stream. Treatments have been completed in May, June, or July since 1971 to avoid possible harm to the adult coasters entering the stream in August and September.

The extended fall fishing season (September), and thus a proportionally higher harvest of coasters in the lower river prior to and during spawning, also could have reduced egg deposition and young fish production in recent years. Historical trends in the river harvest by non- Huron Mountain Club members are unknown, however, an increase in this could conceivably have significantly reduced population numbers.

It is possibie that changes in Lake Superior had as great an impact on Salmon Trout coasters as those noted in the river. The effect of the sea lamprey in the 1950's and early 1960's was devastating on lake trout (*Salvelinus namaycush*). It also severely affected other trout, including coasters. The use of gill nets also killed coasters in Lake Superior, but poachers using

Indians use them now also!

illegal, near-shore sets probably were more damaging than the licensed commercial fishery which operated in deeper, offshore waters. Large-mesh gill nets are no longer permitted except for certain research fisheries. Poaching continues but not to the same degree as in past years. As for the river fishery, data on the lake sport harvest are not available, however, an increased lake harvest over time could have contributed to reduced population numbers.

Game fish populations in Lake Superior have been restored since the mid-1960's by massive plantings of lake trout, steelhead, brown trout, coho and chinook salmon, and splake (*Salvelinus namaycush* x *Salvelinus fontinalis*). Except in a few instances, brook trout have not been routinely planted in large numbers in Lake Superior or its tributaries.

RECOMMENDATIONS

As mentioned before it has been difficult to establish a benchmark of former coaster abundance. Yet such a number is highly desirable when attempting to develop management objectives. It appears that spawning migrations in the 1930's could have included as many as 500–750 adult coasters, perhaps more. The total return in 1969 may have been as high as 300–500. Recent years have produced only 15–25% of that abundance.

Based on available information, a reasonable 10-year objective would be to increase the instream, spawning coaster abundance to approximately 300 adults. A longer term objective would be to increase that number to 750. These numbers include all fish entering the stream to spawn, not just those escaping angler harvest. Spawning populations of these magnitudes would significantly improve sportfishing success in both near-shore waters of Lake Superior and lower Salmon Trout River.

Several programs should be encouraged on the Salmon Trout River both to add to our knowledge of coaster brook trout and to improve the population in the river. Fact-finding projects that do not influence the fish population could be conducted simultaneously. However, management techniques designed to improve the population should be conducted in order of priority and evaluated for a reasonable length of time before proceeding to the next technique.

The following should be considered as ongoing fact-finding projects:

(1) Detailed records of club members' fishing effort and catch should be maintained, preferably throughout the open season but most importantly for the period August 1-31. Records should indicate measured length of all brook trout caught in the lower river.

(2) The Huron Mountain Club should consider purchasing and using equipment to monitor water chemistry throughout the year. The question of possible increased acidity during snowmelt runoff can be best answered by long-term monitoring.

(3) The number and type of spawning beds in the lower river should be counted annually following completion of most spawning activity.

(4) Periodic electrofishing surveys should be conducted in selected mainstream and tributary areas to document population changes. Population estimates should be made for all salmonids.

(5) Law enforcement officers employed by the Huron Mountain Club should be empowered to enforce State of Michigan conservation laws and rules.

(6) No fish species other than brook trout should be planted above the lower dam. Previous plants of rainbow trout have not resulted in natural reproduction but other species may reproduce creating undesirable competition.

(7) Lamprey treatments should continue to be made prior to August when adult coasters enter the stream.

There are several management procedures that conceivably can improve the coaster brook trout population in both the river and in the nearby coastal waters of Lake Superior. They should be put into practice in the following order of priority with each procedure being evaluated individually:

(1) The precise identity of coaster brook trout should be determined before any attempt to change either the abundance or the genetic makeup of the population. The specific question to be answered is whether coasters result from spawning by a migratory strain downstream of the first falls or simply the return of individuals that have drifted downstream from headwater areas as a result of crowding, floods, lack of cover, etc. This question could be partly answered by electrofishing throughout the length of the river system and using identifying fin clips in different locations. Trapping downstream migrants at the mouth of the river could then determine origin of individuals leaving the river. This work should be supplemented with electrophoresis to determine origin of returning adults and whether distinct populations exist above and below the lower falls.

(2) After the coaster brook trout has been defined, attempts to increase the population can be made. First in priority should be improvement of stream habitat by maintaining permanent sediment traps and removing beaver dams throughout the stream system. Sediment traps should be constructed in the following tributaries, with exact locations yet to be determined:

a) Clear Creek: Section 24
b) Snake Creek: Section 23
c) East Branch: Section 5 or 34
d) West Branch: Section 29

Long-term beaver control should include timber management to minimize aspen regeneration within 300 feet of tributary streams.

(3) Yearling (6+ inches) brook trout should be planted in early spring in the mainstream between the lower falls and County Road 550. A minimum plant of 5,000–10,000 yearlings should be planted. All planted fish should be marked with fin clips. Effectiveness of plants should be evaluated by noting the abundance of marked fish in subsequent years' catches. In years when lamprey treatments are scheduled by the U. S. Fish and Wildlife Service, trout plants should be made after the treatments.

(4) The Salmon Trout River should be closed to all fishing after September 1 for a period of 5 years. At the end of the fifth year, an evaluation of the overall effectiveness of this plan should be made. If coaster runs have improved significantly, consideration should be given to modifying this closure and permitting harvest of larger brook trout.

(5) The magnitude of the harvest of coasters in Lake Superior and in areas of the Salmon Trout River which are accessible to the public should be determined. This harvest could be a factor limiting abundance in the stream, especially if harvest is high, relative to the population size.

ACKNOWLEDGEMENTS

W. H. Bullen prepared this report prior to his untimely death in 1987. The manuscript was completed and edited by W. C. Latta, J. W. Merna, and P. W. Seelbach.

LITERATURE CITED

Diana, J. S. 1984. Population status of the coaster brook trout (*Salvelinus fontinalis*) in the Salmon Trout River, Michigan (unpublished). The University of Michigan, Ann Arbor.

Manion, P. J. 1977. Downstream movement of fish in a tributary of southern Lake Superior. Progressive Fish-Culturist 39:14–16.

Smith, L. L., Jr. 1942. A fisheries management program for the waters of the Huron Mountain Club. Ph.D. thesis, The University of Michigan, Ann Arbor.

Smith, M. W., and J. W. Saunders. 1959. Movements of brook trout, *Salvelinus fontinalis* (Mitchell), between and within fresh and salt water. Journal of Fisheries Research Board of Canada 15:1403–1449.

Wilder, D. G. 1952. A comparative study of anadromous and fresh water populations of brook trout (*Salvelinus fontinalis* (Mitchell)). Journal of Fisheries Research Board of Canada 9:169–203.

Approved by W. C. Latta

Word processing by G. M. Zurek

J. Fish Biol. (1988) **32,** 825–833

Variation in the degree of silvering of wild coho salmon, *Oncorhynchus kisutch*, smolts migrating seaward from Carnation Creek, British Columbia

T. E. McMahon* and G. F. Hartman

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

(*Received 4 November 1986, Accepted 28 October 1987*)

Degree of silvering (colouration) is often used as an index of the degree of smoltification in salmonids. To judge the reliability of silvering as an indicator of migratory readiness, we examined the silvering of wild coho salmon, *Oncorhynchus kisutch*, smolts upon entry into the Carnation Creek, British Columbia, estuary. Silvering of migrants was greater in larger fish and increased over the course of the migratory period. Photoperiod appeared to account for most of the observed increase in silvering over time; increased silvering was not correlated with temperature or lunar phase. Overall, 50% of seaward migrants were completely silvered, 45% were in a transitional phase, and 5% still retained colouration characteristics of parr. Colouration thus appears to have limited utility as a reliable indicator of migratory readiness. Our findings suggest that estuarine residence is important for completion of parr–smolt transformation and that acclimation of hatchery smolts in brackish water prior to sea water entry may enhance their survival.

I. INTRODUCTION

Anadromous salmonids that grow through juvenile stages in fresh water for extended periods undergo a series of marked morphological, physiological and behavioural changes in preparation for entry into the ocean (Hoar, 1976; Wedemeyer *et al.*, 1980). Prominent among these changes is a distinct change in colouration from that cryptic for life in streams (vertical bars or ‘ parr marks ’; Donnelly & Dill, 1984) to that cryptic for life in schools in the open ocean (silvery, reflective sides; Denton, 1971). In the transition from the freshwater parr to the seaward-migrating smolt phase, environmentally cued, hormonally regulated pigment changes in the skin and scales result in a loss of parr marks, silvering of sides, and blackening of fin margins (Wedemeyer *et al.*, 1980; Gorbman *et al.*, 1982).

Because the parr–smolt colouration change is so obvious, it is commonly used as an index of other, less visible changes that occur during smoltification (i.e. migratory behaviour, ability to osmoregulate in sea water), particularly in culture operations where it has been used in determining when to release smolts (Mahnken & Waknitz, 1979). Although silvering, increased salinity tolerance and migration generally coincide (e.g. Rodgers *et al.*, 1987), silvering may not be a reliable indicator of smolt status (Kato, 1972; Wedemeyer *et al.*, 1980). In some populations, seaward migration occurs prior to complete silvering or sea water adaptation (Mitans, 1967, 1970; Clarke *et al.*, 1978). In laboratory studies, Johnston & Eales

---

*Present address: College of Forestry and Hatfield Marine Science Center, Oregon State University, Newport, Oregon 97365, U.S.A.

0022–1112/88/060825+09 $03.00/0

(1968, 1970) found that the rate of silvering of Atlantic salmon, *Salmo salar*, smolts was affected by temperature, fish size and photoperiod (see also Kazakov & Kozlov, 1985). Moreover, it has been noted that smolts migrating late in the run are often more silvery than earlier migrants (Solomon, 1978; Rodgers *et al.*, 1987). Variation in the degree of silvering of seaward migrants thus appears common; however, few measurements of the degree of colour variation present in wild smolts have been reported (e.g. Mitans, 1967; Kazakov & Kozlov, 1985). In this paper we describe the colour variation of coho salmon, *Oncorhynchus kisutch*, juveniles migrating seaward from Carnation Creek, and attempt to account for the observed effects of size and time of migration on the silvering process. Our main objective was to judge the reliability of silvering as an indicator of migratory behaviour in juvenile coho salmon. We also aimed to increase present knowledge of the smoltification process in wild coho salmon and therefore provide a firmer basis for designing strategies to maximize survival of hatchery-released smolts.

II. STUDY AREA

Carnation Creek, a small (7·6 km long) stream that empties into Barkley Sound on the west coast of Vancouver Island, is accessible to anadromous coho and chum, *Oncorhynchus keta*, salmon and steelhead, *Salmo gairdneri*, and cutthroat, *Salmo clarki*, trout. The area is the site of a long-term study to examine the effects of logging on coastal rain-forest streams (Scrivener & Andersen, 1984).

Juvenile coho salmon spend 1–2 years in Carnation Creek prior to migrating to the sea as smolts in the spring. Since 1971, an average of 3000 smolts have migrated downstream from late April to early June (Andersen, 1987).

III. MATERIALS AND METHODS

Seaward migrating coho salmon were captured in fan-traps attached to a permanent fish-counting fence located near the mouth of Carnation Creek at the uppermost limit of tidal influence. All migrant fish were captured until stream-flows exceeded 6 $m^3 s^{-1}$; subsamples were obtained at higher flows (Andersen, 1987). Beginning 1 March, fish were removed from traps every morning (08.00–10.00 hours) with more frequent removals during periods of high stream-flow or high fish numbers. Fish were anaesthetized in a 2-phenoxyethanol solution (1:4000), their colouration examined, and fork-length (F.L.) measured to the nearest mm. The anaesthetic had no detectable effect on colouration. Colouration (degree of silvering, fin colour, presence/absence of parr marks) of migrants was categorized according to visual criteria adapted from those described and illustrated in Gorbman *et al.* (1982):

> *parr*—orange fin colour; parr marks dark and clearly evident; little or no silvering of sides.
>
> *transitional*—sides silvery but parr marks still visible; fin colour clear or yellowish [also referred to as silvery parr e.g. Johnston & Eales (1970)].
>
> ' *true* ' *smolt*—parr marks almost or completely obscured by silvering; caudal and dorsal fins clear with black, well-defined margins; eyeball diameter smaller, with surrounding integument silvery.

The colouration of 1449 (73%) of all migrants was examined; the remaining 27% consisted of fish which were removed from traps at night when colouration could not be

PHILOSOPHICAL INQUIRY
An International Quarterly

The journal's intent is to promote research and discussion in all philosophical areas, and to facilitate the international communication of philosophical thought

HONORARY BOARD:
A. AYER (Oxford), N. CHOMSKY (M.I.T.), K. POPPER (London), DAINAIN ZHONG (P.R. of China), W.V. QUINE (Harvard), GR. VLASTOS (Berkeley), P. JONES (Edinburgh), G. CALOGERO (Rome), J. P. ANTON (S. Florida), C. DESPOTOPOULOS (Academy of Athens), I. OWENS (Toronto), P. AGAESSE (C.E.R.P. Paris), G. MOURELOS (Athens), R. KRONER (Switzerland), + M. FARBER (N. York), + E.P.PAPANOUTSOS (Acad. of Athens), + P. KANELLOPOULOS (Acad. of Athens), + C. de VOGEL (Utrecht), + W.H. WALSH (Edinburgh), + H. OSBORNE (London), A. NAESS (Oslo).

CONSULTING EDITORS: P.M. SCHULL (Sorbone Institute Academie des Frances, Morales et Politiques, France), JINGUAN LI (Zhongshan University, P. R. of China), E.L. BURGE (Univers. of Melbourne), H. TENNESSEN (Univ. of Oslo), N. ROTENSTREICH (Hebrew University of Jerusalem), P. DEVUX (Academie Royale de Belgium), K. LYKOS (Australian National University), N. AVGELIS (Aristotelian University of Thessaloniki), V. CAUCHY (Universite´ de Montreal), F.E. SPARSHOTT (Univ. of Toronto), TH. SCALTSAS (University of Edinburg), G. McDONALD ROSS (University of Leeds), GER. SANTAS (University of California), A. CACOULLOS (Athens), K. OEHLER (University of Hamburg), T. J. DIFFEY (University of Sussex), V. KYRKOS (Univ. of Ioannina), J. V. LUCE (Univ. of Dublin), H. MEYNELL (Univers. of Calgary), R. BALASUBRAMANIAN (Univers. of Madras), G. ANAGNOSTOPOULOS (Univ. of California), J. RUYTINX (Univ. of. Brussels), M. REALE (Instit. Brasiliero de Filosofia), M. FAKHRY (Amer. University of Beirut), L. COULOUBARITSIS (University of Brussels), G. VARET (Phil. Docum. Center, France), H.A. MONTGOMERY (Univ. of Auckland, N. Zeeland), J. DING (Zhongshan University, P.R. of. China), I. KUKURADI (Hacettepe University, Ankara), JINGZHAO HU (Zhongshan University, P.R. of China), J. P. SCHOBINGER (Switzerland), A. K. SZABO (University of Budapest), AD. PIATKOWSKI (Univ. of Bucurest), D. R. Le TROCQUER (Univ. of Lyon), B. DZIEMIDOK (Poland), C. HUBER (Pontifica University Gregoriana, Vaticano), J. ZEMAN (Cheskolovenska Academie ved Ustav., Chechoslovakia), C. MICHAELIDES (Cyprus), R. ALLINSON (Chinese University of Hong Kong), R. JUAREZ-PAZ (Universidad Fr. Marroquin, Guatemala), V. TSENG O.P. (Republic of China) A.J. ANTONITES (Univ. of Zululand, S. Africa), TH. TUI - CHIEGH HANG (National Chegcli University, R. of China), L. J. SUZMAN (Univ. of S. Africa), K. B. REMAKRISHNE (Univ. of Mysore, India), W.V. HERMANN (Univ. of Freiburg, W. Germany), J. VAN ESS (Univ. of Tubingen), N. THULSTRUP (Denmark), B. WISNIEWSKI (Poland), A. GOBAR (Univ. of Transylvania), G. WEILER (Tel Aviv University), S. A. JAFELLA DE DOLGOPOL (Argentina), F. BERENSON (Univ. of London), CHR. AXELOS (Univ. of Hamburgh), A. JUFFRAS (W. Paterson C., N. Jersey), S. STOJANOVIC (Univ. of Belgrade), M.M. KARLSSON (Univ of Iceland), T KING - FARLOW (Univ. of Alberta), M KRANAKI (Univ. of Paris) KIM - CHONG CHONG (National University of Singapore).

SPECIAL CONSULTANTS. CHR. BARTSOKAS (Univ. of Athens), R. COULES (Anatolia College)
EDITOR: D.Z. ANDRIOPOULOS
BOOK-REVIEW EDITOR: J. HUMBER
Secretary: H. Andriopoulos

Correspondence, manuscripts, books for reviews and subscriptions: Professor D.Z. Andriopoulos, Editor, Philosophical Inguiry, Aristotelian University of Thessaloniki, POBOX 84, Thessaloniki, Greece or POBOX 3825 C. P. Athens, Greece
Subscription rates for USA and Canada: $ 7.00 a copy, $ 28.00 one year, $ 50.00 two years. For European, Asian and African countries: $ 7.00 a copy, $ 25.00 one year, $ 45.00 two years. For Australia: $ 8.00 a copy, $ 30.00 a year and $ 55.000 two years.
The journal's edition is supported by the Aristotelian University of Thessaloniki, Greece.
Copyright: D. Z. Andriopoulos. All rights resprved.

PHILOSOPHICAL INQUIRY
INTERNATIONAL QUARTERLY

VOL. XI WINTER - SPRING 1989 No 1-2

SOME PHILOSOPHICAL PROBLEMS IN ENVIRONMENTAL ETHICS

Richard A. Watson
Washington University

Introduction

In the following I discuss logical problems, philosophically unsupported arguments, and disturbing social implications in four areas of environmental ethics: 1) eco-philosophy, ecosophy, or deep ecology; 2) eco-religion, ecomysticism, and eco-morality; 2) anti-anthropocentrism and anti-humanism; and 4) the rights of nonhuman animals, nonsentient nature, and abstract corporate entities.

I. Eco-philosophy, ecosophy, or deep ecology

Environmental ethics has naturalistic roots in the science of ecology, the study of the interrelationships among living organisms and their environment, and 'ecosystem' is the most common term used to indicate such a complex. Ecosystems are holistic, something that has led Barry Commoner to formulate what he calls the first law of ecology, which is that everything[1] is connected to everything else. Unlike some idealists, eco-philosophers do not claim that if you are to know fully about anything in an ecosystm, you must necessary know everything about the system, but you must at least understand its total organization and the functional place in that system of the item in question.

Although this general notion of mutual interrelationships necessary for the maintenance of living organisms is at least as old as Aristotle, it was only after Darwin that Ernst Haeckel used the term 'ecology' in 1866 to refer to the study of the "economy of nature". The term literally means "study of the home", and in this sensae it has been used by Marxists, anarchists, and poets to discuss the true economy - a moral or moderated balance - of mankind.

It is important to keep in mind that environmental ethics rises out of the same social and scientific soil as does evolutionary ethics.

Eco-philosophy, ecosophy, or deep ecology is defined by Arne Naess who originated the concept as a "total field model" in opposition to the "man-in-environment" model of living organisms in the environment.[2] His most recent statement of the tenets of "the deep ecological movement" are as follows:

1. The well-being of nonhuman life on Earth has value in itself... independent of any instrumental usefulness for limited human purposes.
2. Richness and diversity in life forms contribute to this value and is a further value in itself.
3. Humans have no right to interfere destructively with nonhuman life except for the purposes of satisfying vital needs.
4. Present interference is excessive and detrimental.
5. Present policies must therefore be changed.
6. The necessary policy changes affect basic economic and ideological structures, and will be the more drastic the longer it takes before significant change is started.
7. The ideological change is mainly that of appreciating life quality (dwelling in situations of inherent value) rather than enjoying a high standard of life (measured in terms of available means)... [making us] less dependent upon material manifestations...
8. Those who subscribe to the foregoing points have an obligation directly or indirectly to try to implement the necessary changes.[3]

Ecophilosophy, ecosophy, or deep ecology is thus conceived of as a radical activist political program. This program involves a drastic reduction of the world's human population. Naess says 100 million humans on earth might be about right to accomodate all forms of life.[4] (I once argued that 500 million, the world's population in 1650, the century of genius in both the east and the West, would be about right for a civilized world.[5]) One of Naess's primary pieces of work is on the relations among humans, bears, sheep, and wolves in Norway.[6]

Naess nowhere argues for his basic claims (1 and 2) that life and diversity of life have value in themselves. Obviously, however, these principles derive from the fact that complex ecosystems with great diversity of life forms have greater stability and survival value in changing environments than do simple ecosystems with only few life forms. This makes deep ecology a form of evolutionary ethics.

More than that, the first principle, that life has value in itself, seems

to be a specification of the principle that whatever is, is good or right. But this is to go too far, and most deep ecologists approve of Aldo Leopold's more limited statement about right and wrong:

> A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends to do other-wise.[7]

The difficulty with this, of course, is that in terms of ecologic balance, simple desert ecosystems are generally just as integrally interrelated and stable as complex rain forest ecosystems. The clue to what underlies the reasoning here is in the inclusion of the notion of beauty. In practice, human beings prefer complex ecosystems because they provide more resources for human use. This may be why human beings think that complex ecosystems are more beautiful than simple ones (among those who prefer deserts, the percentage of misanthropes seems to be fairly high).

Naess is also ambiguous on a question that arises from his third principle, the limits to which humans can go in interfering destructively with nonhuman life to satisfy vital needs. Although deep ecologists do talk of gardening and of animal husbandry, their ideal seems to be to interact with the environment no more distruptively than would primitive hunters and gatherers who live off wild foods and game. The current estimate is that there were about 5 million people on earth in that condition just prior to the agricultural revolution about ten thousand years ago. And as I remark above, in 1650 just prior to the industrial revolution, there were 500 million people on earth. The ideal, then, seems to be some sort of subsistence farming with a technology powered only by men and animals, wind and water, and wood fires, that is, no fossil fuels such as coal and oil giving rise to industrial technology would be allowed.

The thing philosophically most bothersome about this movement is not this winsome pastoralism, but rather the dogmatic assurance with which its proponents assert that life, diversity of life, and complexly stable ecosystems have intrinsic value. This just seems self-evident to them. Also apparently self-evident to them is an animal egalitarianism in which humankind is to occupy no more of the environment (humankind is not to increase in population nor tame the wilderness) than is congruent with all other forms of life fulfilling their capacities. For example, grizzly bears require vast ranges of territory that human beings, on these egalitarian principles, have no right to take over for their own uses. Thus in advocating a human population of 100 million, Naess asks for only 20 times more than the 5 million people on earth just prior to the invention of agriculture in 10,000 B.C., and 500 times less than the 5 billion humans who are alive now.

Naess does propose one sort of argument for these proposals. He harks to Spinoza as the father of eco-philosophy, deep ecology, and environmental ethics.[8] This is difficult to maintain. Of course according to Spinoza, **natura naturata** and **natura naturans** are the same, and so the world is God or God is the world, everything flows from the center, all is one, everything is connected necessarily with everything else, and so on. But as various critics have pointed out, free will is a sham for Spinoza, deep ecology is promoted by fiery individualists such as Naess, and it is at least unclear that Spinoza's system supports revolutionary activity of the sort deep ecologists advocate.[9]

II. Eco-relgion, eco-mysticism, and eco-morality

Deep ecologists think of themselves as Spinozists, basically in the mystical, panpsychic tradition.[10] This view is part of a broad spectrum of people in environmental ethics who call for a new eco-religion, eco-mysticism, or eco-morality.

The morality that is desired is basically the one I have begun to outline above: egalitarianism for all forms of life, indeed, including the environment itself. That is, an ecosystem itself is said to have value (and thus, as discussed below, rights). There are two main lines of development of this notion.

[illegible] The notion that the earth or the universe is itself a living organism is very old. One group of environmental thinkers have developed this notion under the concept of Gaia, the living earth.[11] In this system, human beings are minor parts. It is claimed that far from being wise, human beings are extremely stupid in their belief that they can develop the earth in ways that will enhance either their own well-being or the well-being of other living things or the well-being of the earth itself. Something like this leads Barry Commoner to formulate his third law of ecology, which is that nature knows best.[12] Probably that should be 'Nature' with a capital 'N' in this context.

There is demanded by this view a very severe sense of humility on the part of human beings. In "On the Nature and Possibility of an Environmental Ethics," Tom Regan formulates a general moral imperative for human beings who are part of the total living ecosystem:

> By the "preservation principle" I mean a principle of nondestruction, noninterference, and generally, non-meddling [by human beings in nature]. By characterizing this in terms of a principle, moreover, I am emphasizing that preservation (letting-be) be regarded as a moral imperative.[13]

Besides Spinoza, Heidegger is another philosopher cited as authority for this particular subordination of humankind in the total living environment.[14] The tie here seems primarily to be to those parts of Heidegger's works in which he deplores the development of industrial technology and asks for a return to the folk wisdom and folk ways of a naturally modest and humble local peasantry. A considerable amount of Herbert Marcuse's critique of one-dimensional contemporary society comes from Heidegger.

The claim that the earth or the universe itself is a living organism is based on a notoriously weak and philosophically unacceptable argument. Even if the earth were an organism, there are no satsifactory arguments that it has value in itself or that humans are mere egalitarian parts of it; or, worse, that humans are parasites or a disease of the larger organism. This latter is quite a letdown from Hegel who thought we were the brains.

A Judeo-Christian notion of defilement comes throught very strongly in some of the anti-humanists. David Ehrenfeld, for example, closes his 1978 book, **The Arrogance of Humanism,** with the sentence, "We have defiled everything, much of it forever, even the farthest jungles of the Amazon and the air above the mountains, even the everlasting sea which gave us birth."[15] This is a great exit line, of course, but it illustrates a X paradox in eco-moral thinking. That is, value is independent of man, yet, somehow, only man defiles.

A number of those who call for a new morality or a new religion point to American Indian religions and to Eastern philosophies and religions. My initial feeling about this is one of suspicion. I know that versions of American Indian religions and ways of life as being ecologically wise, balanced, and conservational are highly romanticiced. I suspect the same thing of Anglocized versions of Eastern thought, that they have been cleaned up like the movie **Ghandi.** There is, after all, an enormous amount of misantrhopy, sexism, racism, and cruelty to animals in the East. I am not competent to judge, but few Western scholars who actually know the languages and cultures recommend Eastern mysticism.

If the world or universe is not a big animal, how about its being a big mind? Maybe we are all just parts of a grand thought. Or of something mystical beyond all thought.

My problem here - a philosophical problem - is that although I think I understand what Berkeley means by saying that the world consista of sensible ideas, I cannot get a grip on what it would be for the world to consist of thought or to be mere thought. Does it mean only the way Berkeley, Mill, and Russell, and Husserl, Heidegger, and Merleau-Ponty, worked out the notions of phenomenalism and phenomenology? If so, I take that just to be the world we experience, and to think that world as thought is to think of it as being thought into existence, not as something we experience the way we do in perceiving.

Let me leave that impasse because incomprehension of the ontology of idealism is not really what bothers me here. What I want to know is, suppose the world **is** one big thought or mind, then so what?

Here, I think, is the answer. Just as with the naturalistic ethics of the deep ecologists, the advocates of eco-mysticism or eco-morality base their views about what is good and right on what exists. For example, John Rodman says:

> To affirm that "natural objects" have "rights" is sympolically to affirm that all natural entities (including humans) have intrinsic worth simply by virtue of being and being what they are.[16]

Deep ecologists appear to accept as having value just what happens to exist or what exists because of the evolution of the universe and life on Earth. Mystics seem to base their views about what is good and right on much the same thing, that is, on the way the world spirit thinks or on the world thought or on what is beyond thought. The question is: Do the gods love it because it is good, or is it good because the gods love it?

Here is another problem. I am constitutionally incapable of experiencing religious feelings. I have no moral sense either. I would not bother with this if I did not know that I am far from being alone in these circumstances. Many people have had fine experiences in the wilderness, and have been greatly exhilerated at the completion of difficult mountain climbs and so on. They have felt the awe of the intense silence and sense of aloneness in the wilderness. A surprising number of people have had their fondest sexual fantasies satisfied. Some mystics say that some of these experiences are the same as, or close to being, religious and mystical feelings. Are they kidding? As May West said in the old vaudeville gag when confronted by an exhbitionist, **"That's it?"** When mytics say, "No, it is something ineffably beyond that," then many human beings cannot follow. They atribute their feeling great to having good health, to having accomplished something difficult that they set out to do, to having encountered fine scenery, cooperative lovers, climbable mountains, and so on. Some people argue that people like me have religious experiences and just misinterpret them. Whose interpretation is correct? Both of these explanation-sketches - the naturalistic sketch and the mystical sketsh - are interpretations.

The Enlightenment argument is that religion is based on fear of death and power plays among human beings, and that mysticism is based on misinterpretation of suberb experiences of life (are they so rare? is life so generally awful as Hobbes says it is, so that when we have a good tima we think it must be a gift of the gods?). Religion is dangerous because it is authoritatian and irrational. Mysticism because it is life-denying and irrational. The crucial philosohpical problems here are contradictory principles, ane xperiences or states that transcend ordinary experience and cannot be categorized and discussed, cannot be understood. Are philosophers who are incapable of having religious and mystical experiences more to be pitied than refuted, more to be led along the right path than to be argued with?

I think not. Reason and argument are our only defense against absolutists who know what is for our own good whether we know it or not. Eco-religion, eco-mysticism, and eco-morality have no philosophical grounds of support.

III. Anti-antrhopomorphism anti-humanism, and misantrhopy

A thread of misantrhopy runs through the eco-positions outlined above. It is not just that those calling for a new environmental ethics want to put human-kind in its egalitarian place in balance with other species of living things, it is that many of them seem not to have much liking for humankind in the first place. I agree that there are plenty of grounds for suspicion about the intrinsic goodness of humankind. The earliest written records are about torturing people and genocide? the earlist fossil records of hominids show that brain bashing has been a popular sport for several million years? and the Judeo-Christian myth about being born in sin is not based merely on a human predilection for hanky panky. William James died in 1910 in time to maintain some hope for the human race (despite his own periodic visitations of the horrors), but just six years later his brother Henry died knowing that a million boys were dead and rotting in the trenches. And then anyone who knows history knows that what happened during World War II and since has happened hundreds of times before? the scale of human atrocity merely increases with increase in population and technological development.

Given such natural human behavior, I am not convinced that a return to nature is a cure for human awfulness. Utopians do insist that it is not a backsliding return that is required, but enlightened cooperation rather than competition with nature. The basic problem with humankind, the misantrhopes say, is that instead of living in nature communally, we try to conquer nature. But is this not just human nature?

Most of those interested in environmental ethics are children of the Enlightenment just as I am. They do not believe that human nature is fixed, but that it is malleable, and perfectable. Many of them blame our present maladaptations to and disaffections for nature on the Judeo-Christian religion as does Lynn White, Jr., in his classic paper, "The Historical Roots of Our Ecologic Crisis."[17]

God gave us jurisdiction over the beasts and fields, and he told us to go out and multiply. We disobeyed God in the garden of Eden, so we have to earn our bread by the sweat of our brows, which means cutting down forests and plowing up fields and otherwise using natural resources. We are assured, however, that only human beings have immortal souls. Descartes denied that animals even have feelings of pain and pleasure, so we can treat them simply as things God gave us for our use, as He did trees and mineral deposits. Later on Christ insisted that all that really maters is the salvation of one's soul, increasing the official Judeo-Christian scorn for the things of this earth. Some even say that good works do not matter, while others say that not only will good works get you to heaven, they led to the capitalist revolution.

And please tdo not forget those other people of the Book, the Moslmes, whose influence in the world today is base on - among other religious principles - the belief that anyone who is killed in the Jihad against the infidal non-Moslems is transported directly to Heaven. Powerful stuff, but a little hard for, say, nominal Christians to deal with.

The above two paragraphs are somewhat sarcastic, but this viewpoint is not at all presented by eco-thinkers as an attack on religion and mysticism as such, but as an attack on Judaism, Christianity, and Mohammedanism. In the context of encironmental ethics, the problem with the religions of the Book is that they are all antrhopocentric. All of them make man the center of the universe. For all of them, the universe is

created for man. Only man has any value in this universe; only man has a an immortal soul; only man has even sentience, or, if donkeys and oysters do have feelings, those feelings are much coarser and are not felt as excruciatingly as we feel them. People of the Book are still dealing with the argument that we were wrong to think that there is a scale of sensitivity to pain (and of rights and duties) running from white men of royalty through white freemen and slaves to non-white men to women of all colors.

This anthropocentrism is viewed with a very cold eye by eco-philosophers. I have already outlined some of their programs for decentralizing man. Elsewhere I have analyzed the anti-antrhopocentric program in detail, and conclude that it is grounded on five principles:

1. The needs, desires, interests, and goals of humans are not privileged.
2. The human species should not change the ecology of the planet.
3. The world ecological system is too complex for human beings ever to understand.
4. The ultimate goal, good, and joy of humankind is contemplative understanding of Nature.
5. Nature is a holistic system of parts (of which man is merely one among many equals) all of which are internally interrelated in dynamic, harmonious, ecological equilibrium [18]

And I concluded that the moral imperative derived from this eco-philosophy is that human beings do not have the right to, and should not, alter the equilibrium. All that is, is of equal value.

Arne Naess's eight tenets of the deep ecological movement (cited in Part I) are in response to my summation above, and he has forced me to realize that despite my supersentitivity to threats of authoritarian control, I greatly underestimated not only the extent to which deep ecologists and eco-philosophers beleive that they know what is right for earth and humankind, but also the extent to which they intend or at least desire to coerce, if necessary, everyone into the deep ecology mold. That is, if deep ecologists gained political power, they would enforce vast birth control programs, dismantle much of modern technology, and return enormous portions of the earth's surface to wilderness or natural conditions in which human beings compete (or cooperate) equally with all other forms of life. Deep ecologists believe that the great advantages human beings have because of their superior intelligence in the hierarchy of beasts has been abused. That is, our hubris is in thinking that we know better than Nature how to manage the earth. Deep ecologists heap scorn on the metaphor of "spaceship earth" by pointing out that we know so badly how to run the planet that it will soon be altered far to the worse by air pollution alone, which will cause either a new glacial age or an excessive interglacial rise in temperature, that is, if we do not first burn up the whole surface of the planet and its atmosphere with hydrogen bombs that will further salt the earth with radiation so virulent that no known life forms could take hold here again for a million years. An so on.

What is striking about this apocalyptic rhetoric is how many times we - that is, the human race - have heard it before. Indeed, the great fears of previous times - war, plague, famine, and always death and damnation - are and were just as realistic as our present fears of nuclear annihilation. And also just as real in every case was and is the rise of dogma and dogmatists with the promise that faith in them and their ideas will save us. **We** are just to let **them** tell **us** what to do.

I do not doubt the evidence that humankind depends on ecologic harmony with the natural environment, nor do I doubt the real danger of the nuclear holocaust. But I believe that the eco-philosophers - the eco-crats who would rule us on the holistic model of ecologic balance for our own good-base their anti-humanism on a philosophical mistake. They put the good of the species over that of the individual. And this leads me to the fourth and final problem area.

IV. The Rights of Nonhuman Animals, Nonsentient Nature, and Abstract Corporate Entities

The hero of animal rights advocates is Jeremy Bentham, who said, "The question is not, Can they **reason?** nor Can they **talk?** but, **Can they suffer?**"[19] This point is made foundational by Peter Singer in his book **Animal Liberation** where he says.

> So the limit of sentience... the capacity to suffer and / or experience enjoyment... is the only defensible boundary of concern for the interests of others... The capacity for suffering and enjoyment is **a prerequisite for having interests at all,** a condition that must be satisfied before we can speak of interests in a meaningful way... A stone does not have interests because it cannot suffer.[20]

Later he says that "We ought to consider the interests of animals because they have interests."[21] In relation to human rights, however, nonhuman animal rights are subordinte in teh sense that humans are required to curtail only the unnecessary suffering of nonhuman animals. The concept of 'unnecessary' here is tied to human interests and needs, for if it is in our interest to cause the suffering of nonhuman animals, then it is all right.

I present this travesty of Singer's position (which has been drastically modified in his subsequent publications) to highlight certain problems. Here are some of them: Is sentience a behavioral or a physic phenomenon? That is, does an animal have to be conscious to be sentient? (Consider so-called sensitive plants that respond to touch by drawing away and wilting.) Then, is consciousness enough? To feel pain, does an animal have to know that it feels pain? That is, to be sentient, does an animal have to be self-conscious? These same questions can be asked about the concept of interest. All animals have interests in the sense that they have needs that must be satisfied if they are to survive. But, to go to the heart of the matter, can an animal be said to have interests in a sense pertaining to having rights if the animal does not know itself that it has such interests?

Finally, there is the problem of why the possession of any natural feature - life, sentience, self-consciousness, rationality, language - should be taken to mean that the entity that possesses it has rights. But, then, the environmental ethics literature is so shot through with examples of the naturalistic fallacy that perhaps the message is that these philosophers think it is not a fallacy at all. The problem then would be to argue for the feature that **does** establish that an entity has rights. Unfortunately, many such arguments in the literature reduce either to the position that whatever is, is good or right (I have already quoted John Rodman, for example, who simply announces that "All natural entities (including humans) have intrinsic worth simply by virtue of being and being what they are."[23]), or to the position of evolutionary ethics that what leads to survival is good and raight. These positions reduce in turn to the tautologies: what is, is; and, what leads to survival leads to survival.

A few years ago I argue for a reciprocity theory to explain and justify the attribution of rights and duties. To say that an entity has rights (I argue) makes sense only if that entity can fulfill reciproca duties, that is, can act as an agent. Then to be such an agent, an entity must

1. be self-conscious,
2. understand general principles,

3. have free will,
4. understand the given principles,
5. be physically capable of acting, and
6. intend to act according to or against the given principles.

Only then can entity have, so to speak, rights in its own right.[23]

Thus I argue that a necessary (but not sufficient) feature for having rights is that an entity be self-conscious. So there is hope for my cat, who, on behavioral evidence, is self-conscious. I leave open the question of whether machines or non-living entities can be self-conscious; I see no particular reason why not.

The problems that arise in this debate about rights have to do with questions about human fetuses, badies, idiots, and senile senior citizens. In **Practical Ethics,** Peter Singer has faced many of these questions honestly and fearlessly, as one must who denies that there are absolute values in the universe, as real as matter and mathematics, whether God-given or not.[24] That is, if you play the game of stipulating who and what has rights on the basis of natural features, then you have to be willing to draw lines and cut and fill here and there. For example, if I think self-consciousness is the dividing point, and Herbert Spiegelberg is right that some humans do not have an I-am-me experience until they are seven,[25] then I ought to be in favor of abortion up to and including the seventh post-partum year. That argument (which has in fact been thrown at me) indicates merely that we should not take rules and atributions made up by human beings as being perfectly adequate for every situation. I do believe, nonetheless, that value enters the world only under the scope of the interest, intntions, and actions of self-conscious entities.

But I want to rush on here, to closure with the phantom persons who people the evil empire that threatens us all. Actually, the ral demons are **eminances grise,** but let us look at the phantoms first. In a very important book, **Should Trees Have Standing?**, Christopher D. Stone, outlines a legal technique for protecting nonsentient nature.[26] Entities such as Storm King Mountain are treated as corporate persons who have rights that lawyers can defend.

What is philosophically untenable is that Stone says, in all seriousness and earnestness, that corporate entities "have wills, minds, purposes, and interests that are in very important ways, their own, **i.e.**, that can transcend and survive changes in the consciousness of the individuals who supposedly comprise them, and whom they supposedly serve."[27]

This spectre is bad enough, but in further explication of this concept of legal corporate person, Stone says:

> The legal system does the best it can to maintain the illusion of th reality of the individual human being. Consider, for example, ho many constitutional cases, brought in the name of some hand individual, represent a power struggle between institutions - th NAACP and a school board, the Catholic Church and a schoo board, the ACLU and the Army, and so forth. Are the individua human plaintiffs the real moving causes of these cases - or a afterthought?[26]

Not only does Stone hypostacize institutional legal persons into entitie with wills, minds, purposes, and interests of their own, but also h implies that individual human persons are illusory.
The following quotation from Woorow Wilson expresse my response t Stone:

> Corporations do not do wrong. Individuals do wrong, th individuals who direct and use them for selfish and illegitimat purposes, to the injury of sociey and the serious surtailment private rights. Guilt, as has been very truly said, is always persona You cannot punish corporations...
>
> I regard the corporation as indispensible to modern busines enterprises. I am not jealous of its size and might, if you will bu abandon at the right points the fatuous, antiquated, and quit unnecesary finction which treats it as a legal person; if you will bu cease to deal with it by means of your law as if it were a sing individual not only but also, - what every child may perceive it not - a responsible individual.[29]

Beyond the lawyer's trick of using the corporate person to defen the conspiring executives of General Electric Corporation from the Feder Prosecuters, of Storm King Moyuntain's wilderness from the designin desires of Walt Disney Enterprises what has all this to do with enviro mental ethics?

Everything, I am afraid. That is, in teh literature of environment ethics you read more and more about species and life itself, and less an less about individual self-conscious entities. For example, Garrett Hard in his book **Promethean Ethics** says basically that the individual anim is just a means of preserving the species and so we ought to cull the human herd.[30] That would be done with a triage system where we with the food help some nations and write off others. As for individuals, we are all going to die anyway, so we ought to quit whining about it and think not what our species can do for us, but what we can do for our species. As far as that goes, species become extinct, so we should not think what life can do for our species, but what our species can do for life.

CONCLUSION

I have illustrated the point that a substantial amount of what goes on in the literature of environmental ethics is either in ignorance of or in outright defiance of much that has been accomplished in philosophy since the Enlightenment. Such things as the value and responsibility of self-conscious individual actors, the vacuousness of equating what is good or right with what happens to be or to exist, the arbitrariness (although not necessarily uselessness) of basing rights on the possession of this or that natural feature, the dangers of absolutism, the dangers of irrationalism in religion and mysticism, the inhumanity of true believers, and finally the conclusion based on considerable evidence that the universe, the earth, life itself, species, the church, the state, the family, and McDonnell Douglas Corporation, do not have desires and interests and wills and minds of their own, that corporate entities cannot act, that very cannot have rights except as a legal fiction (not least because there is no way to understand how they could have responsibilities), and - like the gods of Lucretius - they cannot harm us. What can harm us are not the ghosts, but the people in the machines.

It is bad enough to have to watch out for parents who know what the family wants me to do, businessmen who know what the economy wants me to do, presidents who know what the country wants me to do, and popes who know what the church wants me to do; now I have to watch out also for deep ecologists who know what the ecosystem wnats me to do. I am already slated to die for the good of the human species. What bothers me is that there is no philosophical ground for the view that the species - an abstract entity that cannot know or feel - is worth it and that I should love my fate. Let me close with some words from Leonard Wolff's autobiography, written when he was eighty:

> Since the age of sixteen, when for a short time, like all intelligent adolescents, I took the universe too seriously, I have rarely worried myself about its meaning or meaninglessness. But I resent the fact that, as it seems to be practically certain, I shall be as non-existent after my death as I was before my birth. Nothing can be done about it and I cannot truthfully say that my future extinction causes me much fear or pain, but I should like to record my protest against it and against the universe that enacts it.[31]

Leonard Woolf was an atheist who wrote satire. He knew that the universe does not enact anything. His protest was his little joke.

FOOTNOTES

1. Barry Commoner. **The Closing Circle: Nature, Man, and Technology.** New York: Alfred A. Knopf, 1971, p. 33.

2. Arne Naess. "The Shallow and the Deep, Long-Range Ecology Movement: A Summary." **Inquiry,** vol. 16, 1973, p. 95.

3. Arne Naess. "How does the human species live out its evolutionary potentials? A Defense of the Deep Ecology Movement." **Environmental Ethics, forthcoming.**

4. Arne Naess, quoted by Stephan Bodian. "Simple in Means, Rich in Ends: A Conversation with Arne Naess." **The Ten Directions** (publication of the Los Angeles Zen Center), Summer/Fall, 1982, p. 12.

5. Richard A. Watson and Philip M. Smith.. "The Limit: 500 Million." In Edward Pohlman (ed.), **Population: A Clash of Prophets,** New York: New American Library, 1973, pp. 193-201.

6. Arene Naess. "Self-Realization in Mixed Communities of Humans, Bears, Sheep, and Wolves." **Inquiry,** vol. 22, 1979, pp. 231-241.

7. Aldo Leopold. **A Sand County Almanac.** New York: Oxford University Press, 1966, p. 240.

8. Arne Naess. "Spinoza and Ecology." In Siegfried Hessing (ed.), **Speculum Spinozanum: 1677-1977,** London: Routledge & Kegan Paull, 1977, pp. 418-425; "Environmental Ethics and Spinoza's Ethics: Comments on Genevieve Lloyd's Article," **Inquiry,** vol. 23, 1980, pp. 313-325.

9. E.M. Curley. "Man and Nature in Spinoza." In Jon Wetlesen (ed.), "hp 1. Spinoza's Philosophy of Man: Proceedings of the Scandanavian Spinoza Symposium 1977, Oslo: Universitetsforlaget, 1978, pp. 19-16; Genevieve Lloyd, "Spinoza's Environmental Ethics," **Inquiry,** vol. 23, 1980, pp. 293-311.

10. George Sessions. "Shallow and Deep Ecology: A Review of the Philosophical Literature." Unpublished.

11. J.A. Lovelock. **Gaia: A New Look at Life on Earth.** Oxford: Oxford University Press, 1979.

12. Barry Commoner. **The Closing Circle: Nature, Man, and Technology.** New York: Alfred A. Knopf, 1971, p. 41.

13. Tom Regan. "The Nature and Possibility of an Environmental Ethics." **Environmental Ethics,** vol. 3, 1981, pp. 31□32.

14. Michael Zimmerman. "Dewey, Heidegger, and the Quest for Certainty." **Southwestern Journal of Philosophy,** vol. 9, 1978, pp. 87-95.

15. David Ehrenfeld. **The Arrogance of Humanism.** New York: Oxford University Press, 1978, p. 269.

16. John Rodman. "The Liberation of Nature?" **Inquiry,** vol. 20, 1977, p. 108.

17. Lynn White, Jr. "The Historical Roots of Out Ecological Crisis." **In Machina ex Deo: Essays in the Dynamism of Westernb Culture,** Cambriodge: MIT Press, 1968, pp. '5-94.

18. Richard A. Watson. "A Critique of Anti-Antropocentric biocentrism." **Enviromental Ethics,** vol. 5, 1983, p. 251.

19. Jeremy Bentham. **Introduction to the Principles of Morals and Legislation.** New York: Hafner, 1948, p. 311 (from the 1823 edition? first published in 1789).

20. Peter Singer. **Animal Liberation: A New Ethics for Our Treatment of Animals.** New York: New York Review / Ramdom House, 1975, pp. 8-9.

21. **Ibid.,** p. 271.

22. John Rodman. "The Liberation of Nature?" **Inquiry,** vol. 20, 1977, p. 108.

23. Richard A. Watson. "Self-Consciousness and the Rights of Nonhuman Animals and Nature." **Environmental Ethics,** vol. 1, 1979, p. 101. See also "Self-Conscious Rights," **Ethics and Animals,** vol. 2, 1981, pp. 90-92; "Interests, Rights, and Self-Consciousness," **Environmental Ethics,** vol. 4,1982, pp. 285-287.

24. Peter Singer. **Practical Ethics.** Cmbridge: Cambridge University Press, 1979.

25. Herbert Spiegelberg. "On the 'I-am-me' Experience in Childhood and Adolescence." **Review of Existential Psychology and Psychiatry,** vol. 4, 1964, pp. 3-21.

26. Christopher D. Stone, **Should Trees Have Standing? Toward Legal Rights for Natural Objects.** Los Altos: William Kauffman, 1972.

27. **Ibid.,** p. 47.

28. **Ibid.**

29. Woodrow Wilson. "The Lawyer and the Community." **Report of the 33rd Annual Meetings of the American Bar Association,** vol. 35, 1910, pp. 427-428.

30. Garrett Hardin. **Promethean Ethics: Living with Death, Competition, and Triage.** Seattle: University of Washington Press, 1980.

31. Leonard Woolf. **Sowing.** New York: harcourt Brace Jovnovich, 1960, pp. 11-12.

PHILOSOPHICAL INQUIRY, 1989, VOL. XI No 1-2

OBJECTIVIST AND RELATIVIST SCIENCE AND ENVIRONMENTALISM

Joseph M. Petulla

Environmental Management Graduate Program
University of San Francisco

Summary

Objectivist and relativist assumptions of scientific and popular writings need to be clarified by their interpreters. Scientific knowledge is commonly utilized by conflicting interest groups for a confusing array of political reasons. It would be better to state one's commitment and evidence than to appeal to universal laws of principles of ecology or economics.

The major philosophical problems of the twentieth century are also questions of science. Can we evern know the physical world as it really exists? Does scientific objectivity exist in any real sense? Can truth be described at any time as objective or absolute? Or will we always have to satisfy ourselves with relativist descriptions bound by the cultural constraints of laguage and worldview?

These questions simultaneously include problems of language, knowledge, ideologies and culture. Attempts to answer them continue not only for academic reasons but also because science has assumed such a large role in settling public policy questions. People want to know whether or not scientists are telling a slanted version of the truth to government officials who are makking decisions on matters that affect them personally.

Thus the two problems are philosophical and political: how much stock can we put in the statements of scientists and how our friends and adversaries in and our of government are going to use the tatements politically. In a democracy we assume that criteria exist to settle debates among conflicting parties. That assumption rests on the belief that some