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BREATHING AND SWIMMING ACTIVITIES AND BEHAVIORS EXHIBITED BY TWO SPECIES OF CAPTIVE SEA TURTLES (*Chelonia mydas* AND *Caretta caretta*) IN NORTH CAROLINA

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Abstract: Respiration and swimming activities exhibited by an adult male, a female, and six subadult loggerheads and a female subadult green sea turtle were noted biweekly during a 30 week period 9 May through 19 November 1989 and during two observations in 1990. All turtles were held outdoors and exposed to natural air and water temperature and environmental conditions with no manipulation other than feeding every two or three days. Males were more active than females and usually frequented midwater to surface waters. Females tended to stay submerged on the bottom except when breathing. Daytime activity and breathing patterns were statistically significant from those at night for all specimens regardless of season or year of observation. Respiration rates were greater when waters were cool rather than during the summer. Breath interval varied by sex and size of turtles from hourly breathing up to 20 hours for the female loggerhead. The results have far reaching implications in relation to man's attempts to conserve the species and to regulate trawling activities.

Key Words: sea turtles; *Chelonia mydas*; *Caretta caretta*; respiration; behavior; management.

INTRODUCTION

Modern scientists all too often could suggest and better implement effective regulatory and conservation practices if they made more basic observations of the behavior of animals. Observations of activity and breathing behavior of free living sea turtles are often dismissed or rarely noted when attempting to answer such simple questions as the following. How many sea turtles are present in an area? Are the suggested federal trawl tow intervals and times realistic in terms of turtle activity by sex or season? Why do so many female sea turtles strand in comparison to males? Does trawling activity coincide with sea turtle activity? Are sea turtles more or less active seasonally or at a specific time of day? Do sea turtles increase their breathing rates as water temperatures elevate during the summer? And finally how often does a sea turtle breathe?

This report presents information on the activity and breathing patterns of captive adult and subadult loggerhead turtles and a subadult green sea turtle observed for 24 hour periods biweekly between April and November 1989 and 1990 to resolve activity patterns and breathing rates and frequency by sex, season, and size of turtle. The observed patterns were compared to and question suggested

federal regulations of fishing tow time and duration, implicated drowning by the fishery, and population estimate practices (National Research Council, 1990).

METHODS

The activity and breathing patterns of an adult male, a female, and six subadult loggerhead turtles (four male, two female) and one subadult green sea turtle were noted during fifteen 24 hour observation periods within the 30 week period 9 May through 19 November 1989, and during two observations on 25 July and 1 September 1990 at the Institute of Marine Sciences located at Morehead City, Carteret County, North Carolina. The observations made in 1990 were to resolve whether the behaviors noted in 1989 by the unmarked six subadult loggerheads that were held together remained the same when the two females were marked with colored bungee cord harnesses (so no doubt persisted of whether female behaviors in 1989 of unmarked females were really attributable to the females). All study turtles had been raised in captivity following incubation of their eggs. Eggs of the adult turtles were originally incubated at 27.8°C, while the small loggerhead eggs had been incubated at 29.8°C. Their growth rates had also been documented from birth (Frazer and Schwartz, 1984). The adult male and female loggerhead turtles have been kept, at all times, together with the female green turtle. The six subadult loggerheads have also been kept together since birth.

Biweekly, from May through November 1989, observations were made during a 24 hour interval and consisted of noting the activity behavior and breath patterns and rates during hourly 10 min periods. The same was true for observations made during the periods 25 July and 1 September 1990. The adult loggerheads were 21 and 22 years old in 1989 and 1990 respectively. The male straight line carapace length (CL) in 1989 was 846 mm, and he weighed 111.8 kg, in 1990 the CL was 848 mm and the weight 114.3 kg. The 21 year old female loggerhead had a 791 mm CL carapace, and she weighed 101.2 kg in 1989; in 1990 the CL was 791 mm, weight 99.7 kg. The 12 year old female green turtle CL was 625 mm, and she weighed 28.3 kg in 1989; CL was 658 mm in 1990, weight 39.1 kg. The six 12.5 year old subadult loggerheads (four males, two females) had carapace lengths ranging 770 to 863 mm and weights averaging 82.8 kg in 1989; and average 787 to 902 mm CL and weights of 86.1 kg in 1990.

The large adult male and female loggerheads and the subadult green turtle were kept in an outdoor 45,500–l concrete tank, 5.8 x 8.7 × 0.75 m deep, for nine months of the year when water temperatures exceeded a lethal 10°C (Schwartz, 1978). The six subadults were kept together in a similar sized adjacent tank. Each tank was supplied with flow through waters (57–l/min) pumped from nearby Bogue Sound where "normally" water temperatures ranged from 4 to 32°C and salinities ranged from 28 to 34 ppt. The only external night time light, other than moonlight or reflected atmospheric city light, was a single 500 watt quartz light mounted on a building 35 m to the north of the tanks. All other outdoor conditions were as natural as possible.

Food (20 kg to each tank) consisted of mixed fishes and invertebrates fed to the turtles every two or three days. No food was fed 24 hours prior to each activity or breath observation period. Air and water temperatures were recorded continuously, at each tank, by a Beckman thermograph. Water pH's ranged from 7.1

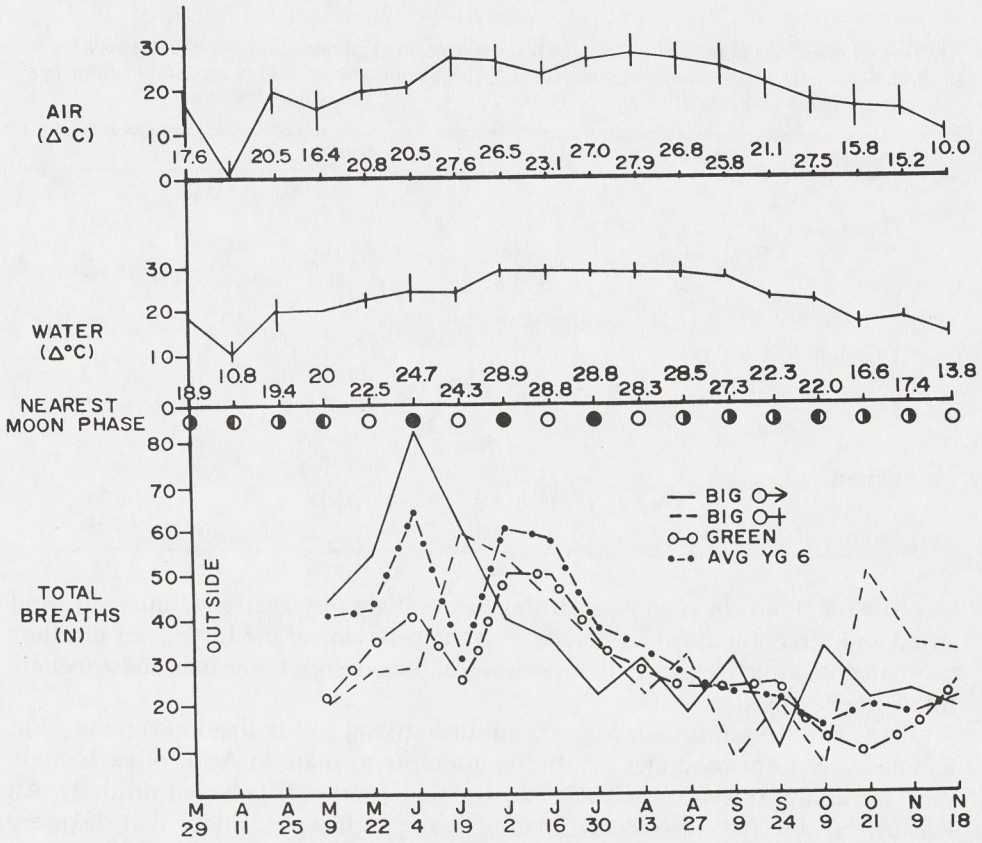

FIG. 1. Air and water temperatures (°C), moon phase, and total number of breaths taken by adult male, female, and six subadult loggerhead(s) and a female subadult green sea turtle taken during each of 15 observational periods, May through November 1989. Vertical bars = range of data. Numbers on upper and middle graph are means for that observation period.

to 7.8 throughout the test periods. Other natural environmental features were: cloud cover, moon phase, wind direction and speed, and rainfall.

The turtles were moved to the outdoor facilities 29 March 1989 and 21 March 1990 and permitted to acclimate to the "natural ambient conditions" for over a month before study. The experiments were terminated in November of each year when water temperatures approached 10°C, which was usually one week after the turtles had been moved indoors to heated winter water facilities. Schwartz (1978) has shown that waters cooler than 10°C were lethal to sea turtles if subjected to prolonged exposure.

OBSERVATIONS

Air temperatures, during the prolonged observation periods, ranged from 10 to 27.9°C in 1989 and 10 to 31°C in 1990, while water temperatures ranged from 13.8 to 28.9° in 1989 and 25 to 31°C in 1990 (Fig. 1, only 1989 data plotted). Several moon phases occurred during the studies yet no changes in swimming or breathing behavior patterns were noted relative to those phenomena. The same

Table 1

ANOVA comparisons of number of breaths taken during day and night 24 hour observations for the adult, male, female, loggerhead, and green turtle. (All 15 hourly observations are combined for 1989 data and are noted in Table 2).

	df	Sum Of Sq.	Mean Sq.	
		Adult male		
Total time	23	1,995.6		
	1	1,104.0	1,104.0	
Error	22	891.6	40.5	F = 27.3**
		Adult female		
Total time	23	1,401.6		
	1	382.7	382.7	
Error	22	1,018.9	46.3	F = 8.27**
		Green		
Total time	23	3,065.3		
	1	1,590.8	1,590.8	
Error	22	1,474.5	67.0	F = 23.7**

was true for cloud cover changes during day or night observations. Rain and wind speed and direction also had no effect on the behavior of the turtles nor did they cause the turtles to frequent other portions of the outdoor tanks than those usually frequented or used.

Other than the adult male loggerhead turtle trying and failing to keep the adult female away from food and exhibiting attempts to mate in April of each study year, the adults and subadult male and female loggerheads behaved similarly. All sea turtles were free to bask by floating at the surface, but those that did were males.

Significantly greater differences were observed (more during daylight hours than at night) in the activity patterns of all turtles during both years (Tables 1 and 2). Even within the subadult loggerhead turtles, the four males were always more active during the day than night, than were the two females (Table 3). Overall the adult and subadult male loggerheads were usually swimming in the water column or at the surface while the female loggerheads preferred to remain or to swim along the bottom until taking a breath. The female green turtle was usually more active at all times than were female loggerheads and swam throughout the water column throughout the day and night (Table 4).

Activity, swimming or breathing, patterns remained the same regardless of age or sex of sea turtle and didn't shift by more than one or two hours throughout the season as daylight lengthened or shortened. The adult male loggerhead was active 75.3% of the time while the adult female loggerhead was active 47.2% of the time in 1989; the female green was active 75.8% of the time while the subadult loggerheads were active 57.4% of the time in 1989 (Table 4). Activity observations for 1990 were: male loggerhead 70%; female loggerhead 52%, subadult male loggerheads 74%, subadult female loggerheads 48%, and female green 79% of the time.

High spring breathing rates decreased markedly from highs (May to June 1989, Fig. 1, and in 1990) to lows in September. Breathing rates increased in the autumn

Table 2

Total breaths/24 hours at specific hour during 15 observation periods May through November 1989 for an adult male and female loggerhead, subadult green, and six subadult loggerhead (four males, two females) sea turtles May through November 1989.

Hour Of Day/Night		Loggerhead		Green	Subadult Loggerheads
		M	F	F	
N	1	13	9	9	99
	2	15	8	7	64
	3	5	12	8	70
	4	4	13	3	84
	5	23	25	14	154
D	6	29	31	33	185
	7	30	22	24	213
	8	35	20	24	194
	9	23	33	37	178
	10	27	23	30	176
	11	32	28	30	213
	12	27	18	23	195
	13	36	23	32	196
	14	31	28	34	182
	15	23	24	30	164
	16	30	28	8	166
	17	31	20	17	123
	18	15	11	14	107
	19	18	17	4	56
N	20	21	28	5	46
	21	18	13	7	53
	22	12	17	7	69
	23	18	13	4	66
	24	9	9	13	61
Total		525	473	417	3,114

of each year as both air and water temperatures cooled even though the total number of breaths was slightly higher in 1990 than recorded in 1989 (Table 5). The breathing differences in 1990 were associated with higher overall study period water temperatures during July to September 1990 than in 1989. Note throughout the study the peculiar inverse breathing rates exhibited by the adult male and female loggerhead turtles. Subadult loggerheads exhibited similar seasonal decreases and increases in breathing and activity patterns to those of the adults (Fig. 1).

The adult male and female loggerheads and subadult female green turtle, breathed more often during the day than at night, regardless of year of observation (Tables 2 and 5). The male and female loggerheads and green turtle usually took at least one breath per hour although as much as 10 hours could elapse between breaths by the adult male, 20 hours by the adult female loggerhead, and 13 hours by the green turtle. The longest interval between breaths for the subadult loggerheads (in 1989 and 1990) was 12 hours (Table 6).

"Charging," a period of multiple and increased breathing, was exhibited by both sexes and species regardless of size or season. This behavior was not especially common at dawn or following a long night or period of breath inactivity, but

Table 3

Breaths taken by four subadult male and two female loggerhead sea turtles during two 24-hour 10 min observation periods 25 July and 1 September 1990. N = night, D = day.

	Hour	July		September	
		M	F	M	F
N	1	14	0	7	6
	2	4	0	8	0
	3	2	0	6	1
	4	8	2	8	2
	5	5	2	8	0
D	6	11	4	19	6
	7	13	5	21	1
	8	16	2	31	3
	9	14	4	17	8
	10	10	2	8	0
	11	5	0	12	1
	12	14	6	17	4
	13	5	0	14	0
	14	15	4	12	0
	15	20	1	8	3
	16	9	5	21	0
	17	10	1	9	1
	18	9	2	8	2
	19	5	1	4	2
N	20	3	0	7	2
	21	8	1	7	0
	22	8	1	5	7
	23	4	0	5	5
	24	5	0	3	9
Total		222	43	265	55

could occur at various hours of the day (Fig. 2). During "charging" the turtles would surface and swim slowly or lay still on the surface lifting their heads only to gulp air for up to 10 times successively per individual prior to resuming "normal" swimming or breathing behavior.

DISCUSSION

The activity and breathing observations noted for the loggerhead and green turtles studied in 1989 and 1990 suggested far reaching ramifications in relation to sea turtle biology and conservation practices. While Milsom and Johansen (1975) noted an increased relationship between lung volume and frequency of breathing, they mentioned nothing as to how breath "charging" affects a turtle. Layne (1952) noted captive loggerheads at the South Boston aquarium surfaced every 2.1 min when actively swimming and every 12.7 min when resting. Parrish (1958) noted captive loggerheads at Marineland surfaced every 10.56 min while resting versus every 30 sec to 10 min when swimming and at night surfaced every 35–45 min. Keinath (1986) noted wild subadult loggerheads off Rhode Island where one surfaced every 2.2 sec and 10 to 27 times per hour while another surfaced every 44.8 sec during two to 69 surfacings per hour spending 79% of the

Table 4

Number of hours during each of 15, 24 hour observational, periods May through November 1989, that an adult male, female, and six subadult(s) loggerhead and a subadult green sea turtle(s) were active, regardless of breaths taken. (360 observations possible for male, female and green, 2,160 for subadult loggerheads).

Observation Period And Month		Loggerhead			Green
		M	F	S*	F
1	M	19	6	74	13
2	M	22	11	92	19
3	J	24	10	99	20
4	J	22	18	111	21
5	JL	19	17	107	22
6	JL	13	15	98	19
7	JL	15	13	89	23
8	A	18	12	92	24
9	A	16	10	75	19
10	S	23	8	75	20
11	S	16	3	71	15
12	O	15	3	91	13
13	O	16	17	75	12
14	N	18	13	24	12
15	N	15	14	67	21
Total		271	170	1,240	273
Percentage of time active		75.3	47.2	57.4	75.8

* Sample composed of four males and two females.

time submerged. Soma (1985) reported an average surface time for a loggerhead off Japan as 79 sec during the day and 53 sec at night. Kajihara et al. (1969) also reported a loggerhead spent only 25% of the time submerged. Lutz and Bentley (1985), Lutcavage et al. (1987), and others have shown that sea turtles spend less than 2% of the time at the surface breathing, a feat accomplished in less than two seconds (Lutz and Bentley, 1985; Dodd, 1988; Lutcavage et al., 1989; our study data also agree with those observations). Lutcavage et al. (1989) have also shown that the sea turtle lung is elastic and reinforced into a highly effective ventilating pump which permits the turtle to take advantage of its air needs during their usual short surface breathing time. Perhaps "charging" seen in this study is needed to make up some sort of additional oxygen deficit; the oxygen being transferred to other tissues, thereby permitting the long intervals between breaths noted. This aspect remains to be resolved. Surely vast lung changes or differences could not be occurring in sea turtles held in the same tank and subjected to identical environmental conditions in the short time devoted to "charging." Also, the peculiar inverse seasonal breathing relationships exhibited by the male and female loggerheads, although unexpected, won't be experienced as lung volume changes.

The prolonged ability to remain submerged may indicate changes in ways oxygen is used rather than lung volume change relationships (Rebel, 1974; Jackson, 1979 and 1985; Lutz and Bentley, 1985; Lutcavage and Lutz, 1987; Lutz, 1988; Lutcavage et al., 1989; Lutz et al., 1989). McGinnis (1968) found breathing rates directly proportionate to the degree of activity and body temperature and suggested

Table 5

Total number breaths/24 hour by an adult male, female, and six subadult loggerheads (four males, two females) and subadult green turtle during 15 observational periods May through November 1989 and July and September 1990.

Observation Period And Month 1989		Loggerhead		Green	Subadult Loggerheads
		M	F	F	
1	M	44	21	22	244
2	M	54	28	34	264
3	J	83	29	41	386
4	J	61	60	25	183
5	JL	40	54	50	362
6	JL	35	44	50	368
7	JL	22	34	33	228
8	A	31	22	28	203
9	A	18	31	24	161
10	S	31	8	24	138
11	S	10	20	25	132
12	O	33	6	13	91
13	O	21	50	9	119
14	N	23	34	14	107
15	N	19	32	25	128
Total		525	473	417	3,114
1990					
	JL	23	23	21	
	S	37	27	37	

a torpor state would exist when water temperatures ranged from 26 to 32°C. This was not the case during this study. In any event, the ability to remain submerged for lengthy periods of time poses problems, in the light of federal proposed regulations of 90 min tow times for shrimping as a means to reduce capture and prevent supposed "drowning," seem irrelevant since our sea turtles have shown that they can remain submerged for 10 to 20 hours depending on sex or species (Table 6). Likewise, suggested federal regulations of alternate intervals of hours of tow or no towing will do nothing to resolve the problem of turtle deaths.

TEDs (turtle excluder devices) have been devised and their proposed and enforced use has been another federal response to ease turtle "drowning." While TEDs release turtles (Watson et al., 1986; Henward and Stuntz, 1987; NOAA, 1987; Christian and Harrington, 1988; Mitchell et al., 1989; Murphy and Hopkins-Murphy, 1989; Renaud et el., 1990), problems still persist with their effective use by the fishery. Thus, our data suggests tow time should be of no longer than one hour for best escapement and survival while insuring negligible mortality. Also other factors, such as stress, may be playing a far greater role in sea turtle deaths (Stabenau and Heming, 1989) than realized. Booker and Ehrhart (1989) have ably demonstrated that turtle mortalities are low during high commercial fishing and high when no fishing has been in effect. Shoop and Ruckdeschel (1989) also report that some sea turtles considered dead will survive if given a period free of prolonged stress.

Sleeping, a condition when the turtle was inactive, often with head drooped down and in such a state that prodding was necessary to arouse it prior to its

Table 6

Number of hours between breaths for an adult male, female loggerhead, and a subadult female green turtle observed between May thru November 1989 (observations during 15 periods combined). Subadult loggerhead observations are for 1990 only.

Hours Between Breaths	Loggerhead		Green	Subadult Loggerheads	
	M	F	F	M	F
1	156	124	114	48	14
2	27	42	36		6
3	11	14	9		6
4	8	6	6		4
5	3	5	7		6
6	4		2		
7	4	2	4		
8	1	1	1		
9			3		
10	1				
11					
12					12
13			1		
14					
15					
16					
17					
18					
19		1			
20		1			

resuming "normal" swimming and other behavior commenced, like that noted by Layne (1952), with sunset and varied between an instant response to that where sleep developed during a protracted sequence or interval leading to immobility. Carr (1952) noted surface sleeping by turtles in the open ocean while Dodd (1988) stated sleeping occurs underwater. Susic (1972) has a different view of sleep, one alternating between states of activity and inactivity that are simultaneous with a non-altered level of body responsiveness.

Both study species also exhibited a sleep pattern where their flippers would continue to move in a slow swimming pattern. This was similar to that noted by Parrish (1958). It is the difference in sleep time and site by each sex that needs to be considered prior to initiating fishing regulations and tow intervals. That is, it would be far better to tow or fish during daylight when females are more active and likely to be off the bottom than at night (Table 2). Such actions would lessen the chances of trawl net-female turtle encounter and capture.

The activity and breathing patterns noted in this study suggest that most aerial survey data used to estimate population levels are completely in error for the aerial count observers usually assume equal numbers of males and females will be counted as on the surface during any one pass of the plane, but that is not the case (LeBuff and Hogan, 1978; Shoop, 1978; Medonca and Ehrhart, 1982; Crouse, 1984; Hopkins and Richardson, 1984; Butler et al., 1987; Lohefener et al., 1988). In reality, aerial surveys are really counting males more often than females. This study has established that males frequent the surface or upper water column waters

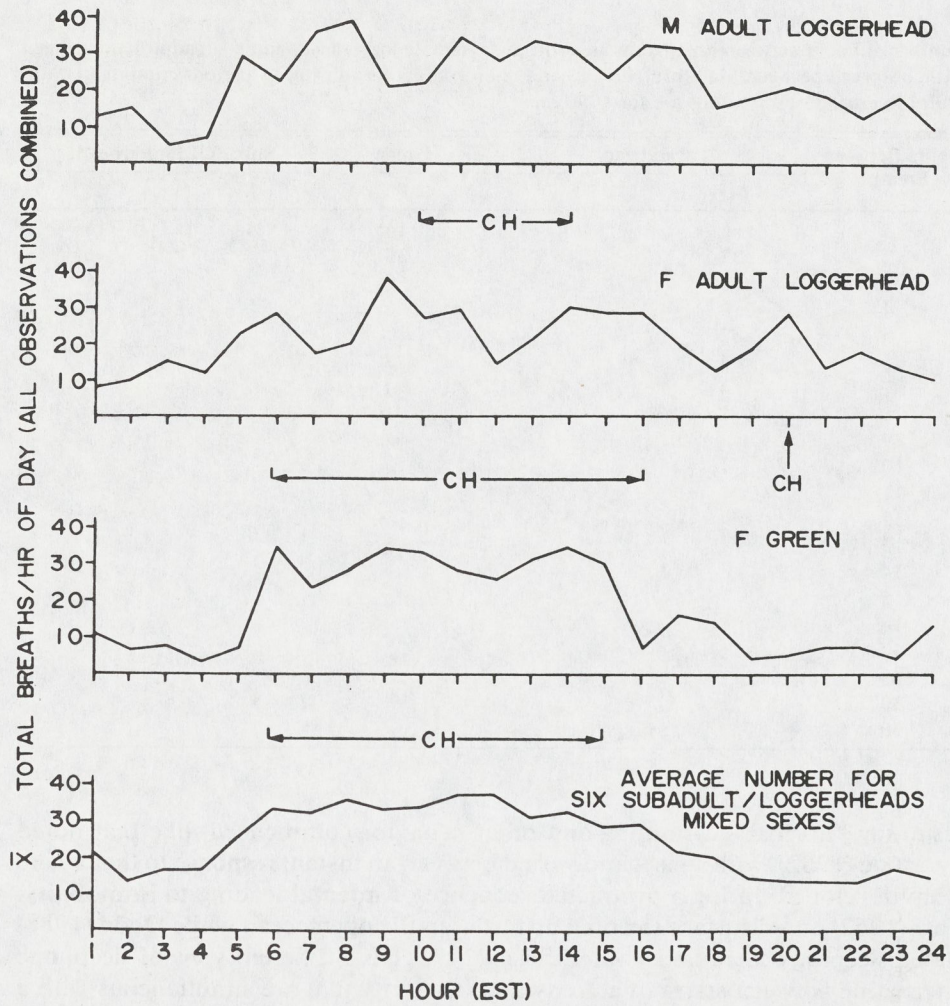

FIG. 2. Total combined number of breaths taken each hour of day and night (total for 15 observational periods) for an adult male, female, and six subadult mixed sex loggerheads and a female subadult green sea turtle in 1989. Ch = period or hours when charging can and does occur.

more often than do females. Hence, better ways of aerial surveying an area need to be developed before real population estimates can be made.

The reason more females are or may be captured in bottom shrimp trawls is related to their behavior of staying or resting on or near the substrate throughout the day or night surfacing only to breathe. Such behavior makes females more susceptible to trawl capture. When loggerhead breathing and behavior patterns (Fig. 2) are compared to trawl fishing use, efforts should be directed to reduce night time trawling as a means of lessening capture. Likewise, suggested federal fishing guidelines of tow time and hours (Wibbels, 1989), duration (not more than 90 minutes) during nighttime trawling are out of synchrony with turtle behavior and should be changed.

Federal regulations should consider the time of year and environmental con-

ditions prevalent when suggesting conservation methods that may affect turtles and would affect commercial fishing activity. Likewise, TEDs may not be the most efficient method of increasing survival of sea turtles. Instead, establishment of sanctuaries (as devised and established by law, NC Law 0.0114 4 August 1980, for Onslow County, North Carolina) along with controlled zone fishing will permit more sea turtles to survive than suggested by practices now in place. Had man observed the behavior of sea turtles first, rather than hurriedly implementing various laws or use of devices, sea turtle science and conservation would be further along than presently understood, regulated, and practiced.

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A LETTER TO THE EDITOR

HAWKSBILL SEA TURTLE FROM POINT CALIMERE, TAMIL NADU, INDIA

ABDUL A. RAHAMAN

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&

FRANK J. SCHWARTZ

Institute of Marine Sciences, University of North Carolina, Morehead City, NORTH CAROLINA - 28557, U.S.A.

Hawksbill sea turtles, *Eretmochelys imbricata*, have been reported from Mandapam Camp southward along India's coastal state of Tamil Nadu (BHASKAR, 1984; KAR & BHASKAR, 1981; SILAS & RAJAGOPALAN, 1984). Likewise, hawksbills are known to nest in the Andaman and Nicobar Islands, well to the east of Tamil Nadu (BHASKAR, 1984; KAR & BHASKAR, 1981) and on the north and south coasts of Sri Lanka (STERNBERG, 1981). Only FERNANDO (1983) noted a hawksbill nesting on the Indian mainland of Tamil Nadu, Tirunelveli coast at Maranpad in December 1980. Whether the hatchling hawksbill captured in a shore seine north of Visakhapatnam(Andhra Pradesh state) represents a stray from a nearby nesting or a migrant from elsewhere remains unresolved (BHASKAR, 1984), as the species is rare north of Sri Lanka (BHASKAR, 1984; KAR & BHASKAR, 1981). Otherwise, the southeast Indian Ocean distribution of hawksbill extends along the southeast coast of India from Mandapam Camp (SILAS & RAJAGOPALAN, 1981) through Palk Bay and the Gulf of Mannar to include Sri Lanka(DERANIYAGALA,1939,1953; BHASKAR, 1981;SOMANADER 1963;WICKREMASINGHE, 1981) and the Andaman and Nicobar islands to the east. Vast nesting was known along the southern Sri Lankan coast in 1834 (KAR & BHASKAR, 1981) whereas, today the species is rare there. Even those cases of food poisoning attributable to hawksbill meat, were from turtles caught at Tuticorin, Tirunelveli district, Tamil Nadu southward (SILAS & FERNANDO, 1984).

Capture of a 26 cm CL (curve line carapace measurement) juvenile female hawksbill at Vizhunthamavadi near Point Calimere, Thanjavur on 19 January 1985 adds to the known mainland occurrence of hawksbills for Pt. Calimere is 50 km north of Sri Lanka and 140 km northeast of Mandapam camp. The specimen was found by a fishermen after it had been washed ashore. It appeared normal in all aspects except that the left front flipper consisted of only a 2cm stump protruding from the body. This caused the turtle to have a tendency to swim in circles.

Measurements (in centimeters) were : carapace width (straightline) 23.5, right front

flipper 14, head length 6, plastron length 19, plastron width 17, left rear flipper 6, right rear flipper 10, horizontal eye length 2, beak 5, distance between eyes 2.25, body depth 8 and neck length 5.5. After detention in a concrete tank supplied with sea water, with several hundred similar sized olive ridley turtles (*Lepidocheleys olivacea*) at the initial stage and later was transferred into Sea Turtle Pen on June 6, 1985. The food preference and the growth of hawksbill are being monitored. Likewise, our specimen constitutes the second smallest survival of a damaged hawksbill (both with missing left front flipper), the other specimen being reported from Brevard County, Florida, USA by REDFOOT *et al.* (1985).

ACKNOWLEDGEMENT

This work was carried out under a Project entitled Sea Turtle Research and Conservation sponsored by the Department of Environment, Ministry of Environment and Forests and Wildlife, New Delhi (No. 14/86/84-MAB/EN-2) and the financial support provided to the first author (Abdul A. Rahaman) is gratefully acknowledged.

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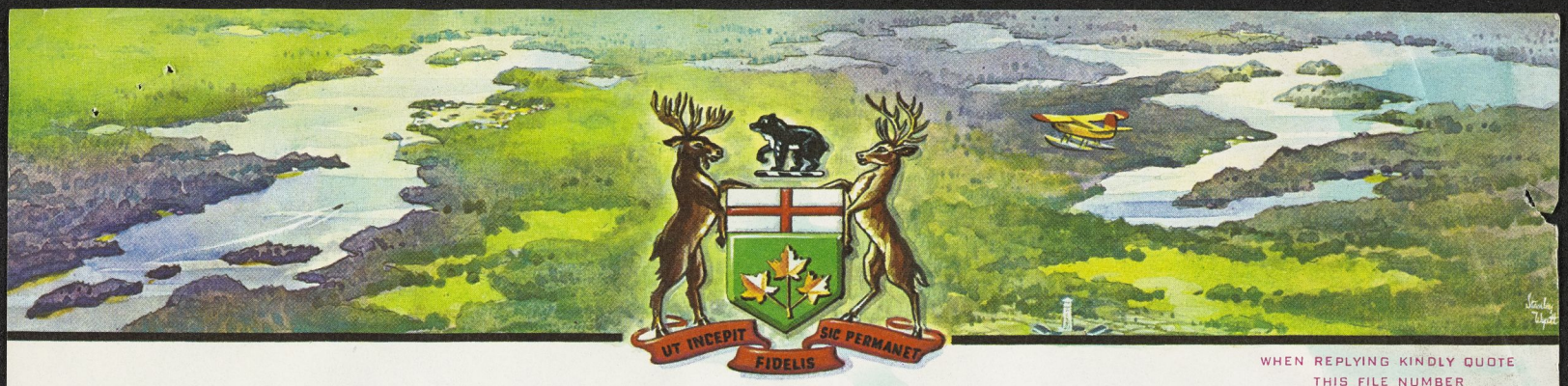

WHEN REPLYING KINDLY QUOTE
THIS FILE NUMBER

ONTARIO

DEPARTMENT OF LANDS AND FORESTS

Glenora Fisheries Station,
R.R. #4, Picton, Ontario,

November 13th, 1970.

Dr. Robert Behnke,
Assistant Unit Leader,
United States Dept. of the Interior,
Fish and Wildlife Service,
Bureau of Sport Fisheries and Wildlife
Colorado Cooperative Fishery Unit,
Colorado State University,
FORT COLLINS, Colorado 80521

Dear Dr. Behnke:

Thanks for your letter and interesting comments. I stand corrected on the catfishes. This was one of those errors that creeps in through the many drafts. I followed Okada in general, and he listed one species in Siluridae and 4 in Bagridae. Whatever is the correct number, it obviously isn't three.

I enclose, with some trepidation, GFS-5-68. It contains many statements I now disagree with, only some of which pertain to the review and were amended for it. Among other things, I doubt very much that my attempt to make sense out of the things I was told about Salvelinus, in Japan contributes anything. The section on Ayu deals with some of the questions you raised and may be of interest. I've often thought it would be useful in view of the paucity of english-language literature on the species, to try to find somebody to publish that section. It could be done as one of our reports but this would not get it circulated to the people who might be interested. I have many of the papers cited here, so don't hesitate to ask for them.

As near as I can tell, acts of piracy and cannibalism during the preparation of the review have made this an unique copy of the manuscript. You can copy it if you wish, but I would appreciate its return. You may keep the extra set of plates. Because of its primitive and tentative nature, I would also like to reserve quotation rights, so if you

thanx

PLEASE QUOTE DEPARTMENT FILE NUMBER IN ANY REPLY

Dr. Robert Behnke, (cont'd)

don't mind, please check with me on any points you consider usable to make sure I still support them.

We already have too many smelts (O. mordax), so I couldn't get very enthused about H. oTidus. I do recall however that Shiraishi has a monograph on them and it was highly regarded. I don't think it has been translated.

We have not caught a char in Westward Lake for 2 years now. It is a pity we didn't save the few we did catch. We will keep any we get in future, for you, but the outlook isn't good. You may be interested however, that I have about 500 yearling Leman char preserved here at Glenora. I traded some lake trout eggs for these with P. J. Laurent in the winter of 1963. They developed an undiagnosed disease in the winter of 1964 and I had to destroy them. Would you like to look at these?

Yours very truly,

Jack Christie

W. J. Christie,
Research Scientist

WJC/ml
Encl.

18th Int. Congress Limnology

1971 (Leningrad)

Villwock, W. "Dangers of introduction of exotic fishes as exemplified by L. Titicaca and L. Lanao".

- trout in Titicaca exterminated endemic cyprinodonts

- carp in Lanao brought red spot disease present production valuable fish now less.

[ca 1970s]

INTRODUCTIONS OF *Salmo letnica* IN THE U.S.A.

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Salmo letnica is endemic only to Lake Ohrid, Yugoslavia-Albania, the most ancient lake in Europe. *S. letnica* and *S. trutta* are closely related. Morphologically and anatomically *S. letnica* and *S. trutta* have slightly different mean values in gillraker, pyloric caeca and vertebrae, but there is no indication of major genetic divergence (Behnke, 1968). Interest in establishing *S. letnica* in lakes and reservoirs in North America, as an alternative to *S. trutta*, is based on certain biological phenomena of the species: A long evolutionary history of lacustrine existence which has resulted in an incipient species flock of "sibling species" consisting of four genetically discrete, sympatric races, spawning at different times throughout the year and a spawning habit of utilizing the lake bottom instead of tributary streams in three of the four races.

Early in 1965, 100,000 eggs were received from Lake Ohrid by the U.S. Bureau of Sport Fisheries and were hatched at the federal hatchery, Manchester, Iowa, and the Lanesboro State Hatchery, Lanesboro, Minnesota. It is not known with certainty, which of the races of *S. letnica*, supplied the original egg shipment. The time of spawning and the subsequent maturation of brood stock at Manchester (late Dec.-January, 1968-69) suggests that the Struga race called *Salmo letnica balcanicus* by Stefanovich (1948) is the form currently being propagated in North America.

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The first stocking of *S. letnica* in North America took place in the fall of 1965 in three small lakes in northern Minnesota. Small fingerling

fish (1054/lb) were used. Test nettings in 1966 and 1967 found no S. letnica in these three lakes, although one of the lakes was reclaimed prior to stocking. In 1968, a total of 1,000 three-year-old S. letnica, averaging 5/lb., raised at the Lanesboro hatchery, were stocked in four Minnesota lakes of varying alkalinity classified from hard to very soft. All of these lakes had established trout populations. Creel census data from two of these lakes (Strawberry Lake of 16 acres and Chester Lake of 49 acres) revealed S. letnica were caught by fishermen beginning in January 1969 with reports of 12 inch specimens. The last reports of July 1969 showed S. letnica specimens of 15-17 inches - a rather creditable growth in these small lakes despite competition from other trout. In 1969 the remaining brood stock at Lanesboro hatchery had not yet attained sexual maturity although now four years of age and averaging 1.3 lb. It was decided to stock these brood fish into a lake most comparable to Lake Ohrid. Big Trout Lake, a 1,418 acre body of water with a maximum depth of 128 ft was selected. Spawning should have taken place in Big Trout Lake in the winter of 1969-70 or 1970-71, but the fate of S. letnica in Big Trout Lake is not known.

The above information on S. letnica in Minnesota is part of a report from Donald Woods to Harvey Willoughby (U.S. Bur. Spt. Fish.) and abstracted in the Sport Fishing Institute Bulletin, no. 210, Nov.-Dec. 1969.

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of two inches (400/lb) by June 24, 1969. About 40,000 survived at Watson Lake hatchery to June 24, but were smaller (1-1/2 inch and 700/lb). The S. letnica from Mt. Shavano hatchery were stocked at the end of June, 1969, in Turquoise Lake, near Leadville and those from the Watson Lake hatchery went into Big Creek Reservoir (32,000) and Parvin Lake (5,000) in August, 1969.

The S. letnica stocked into Big Creek Reservoir received tetacyciline in their diet so they could be separated from S. trutta. Those stocked in Parvin Lake were fin clipped. Supposedly, no S. trutta occurs in Turquoise Reservoir.

In October, 1970, one S. letnica was turned up in an electrofishing survey at Parvin Lake. This trout was 6 inches (S. trutta stocked at the same size and at the same time averaged 9-10 inches and were common along the littoral zones). Evidently S. letnica exhibits quite a different behavior pattern from S. trutta when stocked in lakes - showing a proclivity for more pelagic and benthic life.

S. letnica eggs were also received by Wyoming Fish and Game Department and the first introduction was made September 29, 1970, with 10,296 fingerlings into Viva Naughton Reservoir, a 1458 acre body of water on the Hams Fork of the Green River. No S. trutta are known from the reservoir or the drainage above.

Potential Dangers to Native Fauna

Most rare and endangered North American salmonids are various subspecies of cutthroat trout, S. clarki. The basis for S. letnica introductions is to experiment with a more lacustrine adapted trout mainly for artificial impoundments or lakes without adequate tributary spawning streams - as an

alternative to the exotic S. trutta. Such environments are not habitat for any of the rare forms of cutthroat trout. I can forsee no probable detrimental effect on native fish species, particularly rare and endangered species from S. letnica because in the type of waters where S. letnica are stocked, the fisheries are principally supported by non-native salmonids (S. gairdneri or S. trutta), but any agency undertaking the introduction of any new exotic species should be fully aware of their responsibilities, and unplanned, promiscuous introductions should be avoided.

It is hoped that information can be obtained in 1971 on the performance of S. letnica in various lakes so we may gain some insight into its value as a game fish and its role in the lacustrine ecosystem.

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St. Game & Fish. Comm.
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1968

THE LAKE OHRID TROUT, *SALMO LETNICA*, AND ITS POTENTIAL AS A NEW NORTH AMERICAN SPORT FISH

Systematic Position: *Salmo letnica* (Karaman) is endemic to a single body of water - Lake Ohrid, on the Yugoslavian-Albanian border. Lake Ohrid has a surface area of 348 km^2 and is the oldest lake in Europe. Its lacustrine continuity from pre-glacial times has resulted in a unique composition of relict fauna (Stankovic, 1960).

Salmo letnica resembles the brown trout, *S. trutta* L.; the major distinctions are that *S. letnica* typically have fewer vertebrae and more numerous pyloric caeca and gillrakers than *S. trutta*. The chromosome complement of *S. letnica* is similar to *S. trutta*. I have discussed the evolutionary relationships of *S. letnica* in a previously published paper (Behnke, 1968).

Biological Notes

An interesting facet of the biology of *S. letnica*, suggesting a significant potential for fishery management, is the existence of four, distinct, reproductively isolated populations (or sibling species) separated by temporal and spatial differences during spawning. Three of the four races of *letnica* spawn in the lake itself and do not use tributary streams. The spawning seasons of the various races peak from December-February and in June and July. There are some small average differences in growth rate between the races, but the general maximum size of the commercial catch in Lake Ohrid is 2-3 kg. attained by 5-6 year old fish; although some much larger specimens are occasionally taken

In Lake Ohrid, *S. letnica* less than 40 cm, feeds predominately on crustaceans; above 40 cm, they become highly piscivorous. The cyprinid, *Alburnus albidus*, is the main forage fish utilized.

In Lake Ohrid, *S. letnica*, coexists with several species of cyprinids including the carp, *Cyprinus carpio*. Lake Ohrid supports an important commercial fishery with the total catch approaching 10 Kg. per hectare; *S. letnica* provides about one half of the total commercial yield.

During a visit to the Lake Ohrid Hydrobiological Laboratory, I was told that sport fishing on Lake Ohrid is restricted because *S. letnica* is relatively susceptible to exploitation by angling.

The popularity of *S. letnica* in Yugoslavia as a choice food fish has resulted in its introductions into many new reservoirs. It is believed that most introductions have been highly successful, but detailed published data are not available. Stankovic (1960) included considerable information on *S. letnica* in his book on Lake Ohrid. Stefanovic (1948) published the most comprehensive data on the systematics and ecology of *S. letnica*; an English translation of this publication is available.

The Possible Role of *S. letnica* in Fishery Management in North America

In 1965 the Division of Fish Hatcheries of the U.S. Bureau of Sport Fisheries and Wildlife imported eggs of the winter spawning race of *S. letnica*. A brood stock is now maintained at the Manchester, Iowa, federal hatchery.

S. letnica should be considered as an alternative to *S. trutta* in North American lacustrine environments - or as an addition to established *S. trutta* populations. Some of the possible advantages are: 1. A long evolutionary history of lacustrine adaptation and specialization. Highly

specialized lacustrine forms of *S. trutta* have not been introduced into North America. The majority of *S. trutta* introductions were of fluviatile populations. Although the Loch Leven trout may have existed in Loch Leven, Scotland, for several thousand years, this is only a fraction of the time *S. letnica* has been evolving in Lake Ohrid. 2. Spawning in a lake without the necessity of suitable tributary streams for reproduction. 3. Co-existence with and utilization of cyprinid species. 4. Possibly more vulnerable to angling than *S. trutta*. 5. If more than one race of *S. letnica* could be established in a lake the total population should increase due to year-round recruitment and subtle ecological differences of the different races allowing for more efficient use of the environment.

There is need now for evaluation of *S. letnica* introductions into North American lakes and reservoirs. Cooperation between fish culturists to successfully raise *S. letnica* to fingerling size in large numbers and fishery biologists to select the waters and carry out the evaluation will be necessary.

As a preliminary study, Colorado Game, Fish and Parks received about 150,000 eyed eggs of *S. letnica* from the Manchester hatchery in February 1969. Most of the fry perished and perhaps only about 75,000 fingerlings will be available for introductions.

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Report of the Exotic Fishes Committee

1971

James E. Deacon, Chairman

The Exotic Fishes Committee has functioned entirely by correspondence. Serveral areas of endeavor were identified as being of prime concern for this committee as follows:

Intracontinental movement of undesirable fishes: Much discussion, correspondence and deliberation has yielded no apparently desirable or workable way of handling this problem nationally or internationally. Nearly all state and provincial fishery biologists recognize the existence of the problem but there seems to be no uniform means of handling the situation that the subcommittee of the AFS Exotic Fishes Committee could recommend. Further deliberation on this matter is desirable.

List of undesirable fishes: We are not prepared to offer a list of fishes recommended for restriction from North America or from any specific North American country. The tentative list developed last year from a compilation of state lists is not widely acceptable to the committee. Some species on that list are actually native to North America and therefore must be deleted. Others are controversial and specific decisions regarding their desirability must be made. No concensus has been achieved within the committee. An alternative of developing a reference volume listing fishes permitted for importation

has been discussed. Such a volume could be developed in loose leaf format to permit maximum flexibility.

Consideration of new federal regulations: The following recommendations developed by H. Axelrod were circulated to the committee. Sinch no specific revisions or objections were brought forth I submit them as a recommendation of the committee. We believe these points should form the basis for new fish importation regulations by the governments of North America.

1. Every shipment of fishes from a foreign source be accompanied by a duplicate bill of lading which will list by carton number, the quantity and species name, and the source of the fish.

2. Every carton of fishes must contain one and only one species per plastic bag (sometimes there are more than one bag per carton).

3. Every carton must be numbered and labeled with name of shipper and consignee.

4. Every unit of fish (carton or plastic bag) must be identified as to original source (whether the fish has been bred, locally collected, trans-shipped).

5. Every shipment of fish should be accompanied by a statement from the local fish authority certifying to the information contained in the accompanying bill of lading.

6. A duty of 1¢ per fish plus 10% of the freight cost should be assessed on all fishes imported into this country alive to finance the enforcement and additional training of customs or other official people.

7. The government should have the right and the responsibility to remove any or all dead fish from importations, and samples of some live material from these same importations and send them to the appropriate National Museum for verification of the identification as well as for adding specimens to the national collections. Further, qualified fish pathologists should have access to the living, freshly preserved or dead material to ascertain whether potentially harmful or proven harmful organisms are piggybacking their way into American fisheries via exotic species.

8. All fishes which are being successfully bred in North America should be subjected to treble duties, both to restrict their importation and to encourage fish farming. Every imported fish is likely to be a disease carrier, therefore why take unnecessary chances?

9. Dealers in live fishes should be licensed and tested to be sure they can identify prohibited species.

10. The federal government should circulate up-to-date information to all licensed fish dealers regarding the status or changes in status of fish species.

Recommendations regarding introduction of various species: The enclosed studies have been completed by the individuals indicated with each report. The entire committee concurs or at least has raised no objections to the recommendations. We therefore submit these studies, suggest that they be published in the Transactions of the American Fisheries Society with the authors name but bearing the endorsement of the Exotic Fishes Committee and the AFS. Reprints should of course be provided to the authors, committee chairman and the executive secretary for distribution to interested people and organizations. A report on one additional species, Esox reicherti, amur pike, is in preparation.

Feasibility of introduction of the Nile perch, Lates niloticus, into the United States

Because of its size, abundance, and quality as a game and food fish the Nile perch is perhaps the most renowned of African freshwater fishes. Its consideration for introduction into the United States therefore seems appropriate.

The genus Lates (family Centropomidae, which includes the American snooks) consists of eight species. All are of moderate to large size, attaining a length of more than one-half meter. Lates calcarifer, the barramundi perch or giant perch, is an estuarine species, widespread along Indo-Pacific shores from southern and eastern Asia to northern Australia. The other species are restricted to freshwater lakes and rivers of tropical Africa, and all seven are sometimes referred to as Nile perch. In a strict sense, however, that term applies only to Lates niloticus (Linnaeus), the largest, most widely distributed, and most familiar species. Three other species of Lates are restricted to Lake Tanganyika, two are endemic to Lake Rudolph in Kenya and Ethiopia, and one lives only in Lake Albert in Uganda and the Congo. There is no apparent reason why any of these six species would be any more suitable or desirable for introduction in the United States than Lates niloticus, and they are not considered further here.

Lates niloticus is widespread in Africa; it occurs in west African rivers from the Congo to Senegal, in Lake Chad, in Lake Albert, and in the Nile from Murchison Falls, Uganda, north to the delta below Cairo. It has been recently introduced with notable success into Lake Kyoga on the Victoria Nile, Uganda, into Lake Victoria, where it is as yet uncommon, and into several other lakes and tanks in Ethiopia, Kenya, and Uganda. In 1968 S. H. Midgley, an advisor on freshwater fish in Queensland, was sent to Africa for several months to survey the suitability of introduction of Nile perch into tropical inland waters of Australia. Mr. Midgley's report and P. H. Greenwood's "The Fishes of Uganda" (1966) provided much of the information used in this statement.

Judgment of the game quality of the Nile perch, as for many sport fishes, varies according to the informant but the high palatability of the flesh is not debated.

Throughout its area of occurrence it is valued as a sport and a food fish. Nile perch occasionally attain a length of nearly two meters and a weight of over 100 kilos (netting record 164 kilos=360 pounds); thus, the species qualifies as a trophy fish of distinction. Young Nile perch feed on invertebrates, chiefly insects and prawns, but adults are primarily piscivorus. The breeding habits are not known. The species lives in both clear and murky waters, in large rivers, and in shallow lakes. In Lake Albert it is found mostly in sheltered bays and shallow waters, but it descends occasionally into water more than 20 meters deep occupied by the sympatric Lates macrophthalmus, a smaller species.

The ecological impact of successful introduction of a large predator such as the Nile perch on an American fauna is, of course, difficult or impossible to predict. Ecologists have observed horrible catastrophes and dramatic successes aplenty to emerge from introductions, whether irresponsible or seemingly well designed.

To be successful, however, the introduction of Nile perch into the United States must accomplish the major physiological adjustment of a tropical organism to a temperate climate. The range of the Nile perch in Africa lies wholly within the tropics except where it extends downstream in the Nile to near Aswan (Lat. 24°) and, at least formerly, to below Cairo (about 30°). No species of Lates occurs in the Zambezi or other waters of Africa south of Lake Tanganyika. Prevailing water temperatures in the natural range of the Nile perch are between 20° and 30°C., falling to winter lows of 18°C. in Lake Chad and 16°C. in the Nile below Aswan. Lakes inhabited are nearly isothermal, with differentials of about one or two degrees from surface to bottom.

It should be noted that the lower Nile, where the species is subjected to minimal natural temperatures, is in direct communication through a major dispersal route with the heart of the species range within the tropics. If periodic cold mortality should decimate or eliminate the population of the lower Nile it could, at least prior to construction of Aswan Dam, be repopulated by downstream movement.

Mr. Midgely attempted a series of aquarium experiments at Jinja, Uganda, to determine tolerances of Nile perch. He found that they fed at temperatures from 21° to 18°C.

Temperature experiments were not conclusive, but indications were that the fish should not be subjected to levels below 15°C. (59°F). Field tolerances of range of pH acceptability were 7.0 to 9.7, conductivities of 700 down to 95, and dissolved oxygen of 8 ppm to 3.8 ppm.

Because of the apparently demanding lower thermal limit it seems unnecessary to pursue further the ecological requirements of the Nile perch. Natural lakes and large rivers in the United States with few exceptions have winter minima far below the indicated 15°C. tolerance. Cold snaps even in southern Florida bring subfreezing air temperature and G. Gunter and G. E. Hall (1963, Gulf Research Reports, 1[5]: 222) have recorded a low temperature of 58°F (14.4°C.) in discharge waters from Lake Okeechobee. Periodic if not yearly winter mortality from cold is predictable even in this subtropical area.

In view of the foregoing it is suggested that the Nile perch is not a realistic or suitable fish for introduction into natural waters of the continental United States or Canada.

Prepared by

Reeve M. Bailey

12 July 1971

THE INTRODUCTION OF EXOTIC ANIMALS INTO THE UNITED STATES

Since the earliest days of its history, the United States has served as the testing ground for the intentional and accidental stocking of literally thousands of animals from abroad. Fortunately perhaps, most of the arrivals failed to establish themselves. Some, such as the Norway rat, starling and house sparrow have become our most pernicious pests. Yet, several deliberate introductions have proved to be valuable additions to the native American fauna, and support substantial recreation-oriented economies.

After the War of Independence, the United States rapidly developed a great interest in the close examination and description of its wildlife. During the end of the eighteenth and the beginning of the nineteenth centuries, the Atlantic seaboard was the center of this scientific inquiry, the land west of the Appalachians being largely unexplored and poorly known. It attracted men whose one great ambition was to explore and describe the flora and fauna of that region.

One eighteenth century investigator was the Swedish naturalist, Pehr Kalm (1716-1779). He expressed his feelings saying, "I everywhere found such plants as I had never seen before. When I saw a tree, I was forced to stop and ask those who accompanied me how it was called. I was seized with terror at the thought of ranging so many new and unknown parts of natural history." He was followed by the Scotsman, Alexander Wilson, who became known as the "Father of American Ornithology," and later by the great Audubon. All found in this new country pristine flora and fauna. The land these men, and many more of their kind, must have seen was virgin wilderness--exposing to their amazed eyes the species of the new world--spectacular and different in color, habit, and habitat.

The European scientific world was eager for examples of the American fauna and flora, and in the early nineteenth century, John Bartram, the Pennsylvania naturalist, initiated what was probably the first exchange of living material between this country and the rest of the world. He was employed by various English noblemen to collect and gather native American plants and trees, and these he shipped for naturalization to England. His efforts alone resulted in the successful export to Europe of 150 American plants. He corresponded with the great Linneaus, various Scottish, French and Russian scientists--all eager to share in this first beginning exchange between the new and old worlds.

Presented by John S. Gottschalk, Director, Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, at the Ninth General Assembly and Tenth Technical Meeting, International Union for the Conservation of Nature and Natural Resources, Lucerne, Switzerland, June 1966.

Since the days of these early naturalists, there has been an ever increasing exchange of animals between the United States and other countries. Over the years this activity has grown from the importation of a few specimens to operations involving thousands of animals. Prior to our Foreign Game Introduction Program, which started in 1948, the efforts were largely unplanned. Since the formal Program has been initiated, we have attempted to enhance the American biota in a small but highly sensitive manner, matching relatively unpopulated ecological niches with game birds, mammals and a few fishes from other countries. The plan is to stock our vacant habitat with suitable exotics.

The Foreign Game Introduction Program is a cooperative venture involving the United States Department of the Interior through the Bureau of Sport Fisheries and Wildlife and the various State fish and game departments. The program has also involved many foreign governments and various private organizations, particularly the Wildlife Management Institute of Washington, D. C.

PHYSIOGRAPHIC DIVISIONS OF THE UNITED STATES

The past and current introduction efforts in America will best be understood with an understanding of the nation's natural and cultivated environments. Equally important is the comprehension of the social and economic forces which have prompted Americans for more than two centuries to bring into this country new and different animals.

The land and inland water area of the United States totals about 2.3 billion acres. In the conterminous 48 States, about 400 million acres are in cropland; 700 million acres in pasture and range, and 600 million acres remain in forest and woodland. These areas of forest, range and farm, support the wildlife populations of America.

Wildlife is a product of the soil; its capacity to produce game crops is related to fertility. We might, accordingly, expect to find the best hunting on the richest soils. However, this is not often the case, because the fertile lands are those most intensively farmed or developed. In the process, one or more requirements of a species, such as nesting cover, food plants, or winter cover are reduced in abundance and quality, or eliminated entirely. For instance, in many areas of the Midwest, the cornlands are so thoroughly cultivated that suitable nesting cover is at a premium and often winter cover is in short supply. Pheasants and bobwhites, which otherwise would be numerous, survive only in scattered sites where all of their life requirements are met. These relationships will be discussed subsequently in greater detail.

From east to west across the Continent, the United States has five major geographical divisions:

a. The Atlantic and Gulf Coastal Plain.
b. The Appalachian Highland.
c. The Interior Plain.
d. The Western Highlands.
e. The Pacific Slope.

The nature of each will be discussed as it relates to game production capabilities.

The Atlantic and Gulf Coastal Plain is a gently rolling area extending from about New Jersey southward and westward to Florida and Texas. The soils are generally sandy, but the clay content increases westward. Originally, the lands were covered with mixed hardwoods and conifers in the north, and conifers (predominantly pines), in the southern regions. The cleared and cultivated portions are devoted to corn and small grains, tobacco, cotton, pasture crops. Forestry, especially pulpwood production, is intensively practiced, and industrial and urban development is extensive and increasing.

The coastal marshes and stream courses provide wintering habitat for many species of waterfowl and shorebirds such as snipe and woodcock. They are important producers of rails as well as several non-migratory species of duck. Inland, quail, white-tailed deer, wild turkeys, doves, rabbits and squirrels are the primary species hunted. Present land use trends indicate increasing competition for available area, and the long-range outlook for game increase is not bright, except for the mourning dove.

The Appalachian Highland extends in a north-south direction from the New England States to Alabama. It encompasses, from east to west, the Piedmont, or hilly foothills, the mountain ranges, the ridge and valley province and the plateau which slopes toward the Mississippi valley. The most fertile soils occur in the foothill and flood plain areas. The original cover type was mixed deciduous and coniferous trees and a high proportion of it remains in forest today although it has been cut over many times. In the north, deer, bear, grouse, pheasants, hares and rabbits are the principal game species. To the south, turkeys and quail replace the grouse and pheasants, and squirrels become increasingly important in the game bag. In the tillable portions, diversified farming and orchard crops are important. The intensity of cultivation and forestry practices control the suitability of the land for wildlife. For the most part, the trends are inimical, but the opportunities for wildlife enhancement through management are very good, especially in the forests and woodlands.

The Interior Plain stretches from the Appalachian plateau on the east to the Rocky Mountains on the west and from the Canadian border southward to the Gulf Coastal Plain in western Kentucky, Tennessee, Oklahoma and Texas. It is the primary agricultural region of the United States. Generally, the soil is fertile and is devoted to a cash grain and grain-livestock economy. The area surrounding the Great Lakes is less fertile and remains primarily forested with conifers, mixed conifers and hardwoods. The eastern areas, once covered with deciduous forest, are now largely cleared for cultivation. Proceeding westward, rainfall diminishes and there was originally a transition from hardwoods, to savannah, to tall grass, and finally short grass prairie, in an area that is now largely under cultivation or managed for livestock production.

In the forest, deer, black bear, ruffed grouse, hare, rabbits, and squirrels are the major game species. The cultivated lands support pheasants, European partridge, bobwhites and rabbits. The grasslands sustain prairie grouse, antelope, white-tailed and mule deer and jack rabbits.

The wetlands, especially those within the prairie and plains provinces, are important producers of waterfowl, including mallard, teal, pintail, gadwall and shoveler.

Intensive cultivation, "clean" farming, wetland drainage and heavy grazing have reduced game production. In recent years, efforts to control crop surpluses through the withdrawal of lands from cultivation, and the creation of farm ponds and stock tanks have resulted in improved conditions for wildlife. Opportunities for wildlife enhancement through the modification of agricultural practices are unlimited. Research is needed, however, to insure the harmonious integration of wildlife and agricultural production goals.

The Western Highlands including the Rocky Mountains extend southward from the Canadian to the Mexican border, and west from the prairie and plains to the Pacific slope. The topography is rugged, rainfall is scanty, and settlement is limited to the plateaus and stream valleys. Forestry, mining, grazing, and irrigation farming are the major income producers. Although much of the soil is fertile, aridity and topography cause severe limitations over most of the division.

The Rockies are famous for big game: grizzly and black bear, moose, elk, bighorn sheep, mountain goats and mule deer. Locally abundant are turkeys, ruffed and blue grouse, sage hens and prairie grouse, several species of quail, chukar partridge, and jack rabbits. Waterfowl are produced in some quantity on natural and artificial waters. These also attract great numbers during migration and wintering periods.

Agricultural development of the alluvial deposits along water courses has usurped the winter range of deer and elk; this, with overgrazing, and occasional harvest unbalance, are the main problems faced in wildlife management. Enlightened forest and range management practices are contributing much to sustain game production. The low density of the human population and lack of access facilities have prevented the full utilization of many big game herds.

The Pacific Slope valleys and the coast ranges lie west of the Sierra Nevada and Cascade ranges. The climate is milder, rainfall more abundant, and soils generally quite fertile. Grouse, deer, elk, bear, quail, pheasants and chukars are the important resident game species. Also, waterfowl are produced in fair abundance in the northern areas, and the southern stream valleys, reservoirs, impoundments and coastal waters provide attractive wintering grounds.

The salubrious climate, natural resources and transportation facilities have resulted in industrialization and urbanization at rapid rates. Forestry, truck and fruit crops, and manufacturing have had a deleterious effect on game habitats. These, together with the rate of human population growth, do not permit a favorable forecast for wildlife unless comprehensive conservation programs are undertaken and practiced.

FISH HABITATS IN THE UNITED STATES

The extremely varied fish fauna of the United States reflects the great diversity in aquatic habitats of the country. Starting with the Atlantic coast in the east, there are a great number of large bays and sounds, coastal indentations, estuaries, and a complex of small streams that flow into the sea.

Moving inland, the streams of the Piedmont and upper coastal plain support resident species of pickerel, catfish, sunfishes and minnows. These streams have suffered from deterioration of the environment and many contain barriers to the migration of anadromous species. Many reservoirs have been created to produce electric energy, control floods, and for navigation.

The great Mississippi River system drains the central part of our country from north to south and supports a varied fish fauna from the trout in its headwaters to warm water species in its lower reaches. In the Rocky Mountains, in the Sierra Nevada and west coast ranges, varieties of salmonids were and are the primary species. Finally, the streams draining into the Pacific, including the mighty Columbia, have long been known for their runs of salmon and steelhead trout. Dams here create problems owing to the interruption in migration of anadromous species.

Originally, flowing streams were probably our country's most characteristic aquatic habitat. These streams provided an estimated 913,000 miles of fish-supporting water and covered over 6,250,000 acres. Currently, more than 50,000 miles of these streams are classed as unproductive.

The past 50 years have seen a rapid growth in impoundments ranging in size from less than an acre to large reservoirs approaching 200,000 acres. In 1960, total acreage contained in reservoirs was listed at 10,655,000 acres, at average minimum water levels. Included in this figure were more than 2,000,000 farm and ranch ponds covering a like number of acres. The number of farm ponds (reservoirs of not more than 10 surface acres) is increasing rapidly and presently approaches 2,000,000. Likewise, the number of large reservoirs and the acreage covered is growing and presently totals more than 12 million acres. Parts of the country are also endowed with natural lakes which encompass 9,330,000 acres. Fish habitat conditions have remained favorable in most of the natural lakes.

As the population of the nation grew, changes occurred in the free-flowing streams. These first appeared along the eastern seaboard, but gradually occurred westward as civilization gained momentum and use of natural waters became more extensive and less favorable to fish life.

Diversion of water for irrigation, municipal and industrial uses, reduces fish habitats both in quantity and quality. Pollution from industrial waste, acid mine waters, and other chemical substances, including pesticides, has affected fish production in many of our streams. More than 10,000 miles of streams are seriously affected by acid mine pollution alone.

The acres of impoundments whose productivity is seriously lowered by pollution, run into the hundreds of thousands. Additions of partially treated sewage frequently stimulate growth of aquatic plants and may, under some circumstances, increase fish production. However, excessive algal growth is deleterious.

The productivity of natural and impounded waters varies greatly over the United States. In cold headwater lakes and streams, in acid bog waters and large open expanses of the Great Lakes, production may amount to only a pound or two of fish per surface acre. In contrast, rich overflow lakes and fertilized farm ponds may support several hundred pounds of fish per surface acre, and in commercially managed ponds 2,000 pounds or more per surface acre are grown. Over the centuries, man has learned to increase the productivity of water as he has the land. It may be increased by application of fertilizers to grow agricultural crops; by changes in chemical content such as a reduction of natural acidity and an increase in minerals. Erosion and siltation reduce productivity as may the over abundant growth of aquatic plants, the latter bringing about changes through tying up nutrients, depleting oxygen and interfering with normal predation and harvest of fish that may be present. Naturally unproductive waters may benefit from our present knowledge of management procedures, although these are often difficult to apply on large water areas.

The following types of aquatic environments in the United States are not fully utilized at the present time:

1. Large streams and rivers, where water temperatures go into the 80's during summer, reach freezing in winter, contain some pollution in the form of silt, agricultural and industrial chemicals and organic substances.

2. Shallow warm water habitats where aquatic weeds are a serious problem.

3. Small ponds and reservoirs in northern latitudes, incapable of supporting trout, but not suited to the bass and bluegill combination.

4. Small streams below the trout producing zone, but not suited to present "river" dwelling species.

5. Large reservoirs, where two types of fish are needed:

   a. Phytoplankton feeders, capable of converting minute plant life directly to useable fish flesh.

   b. Large predators that can deal successfully with abundant forage species, such as the gizzard shad, and contribute to sport and food.

HISTORY OF THE ANIMAL INTRODUCTION PROGRAM

The history of the introduction of foreign species into the United States can be separated into two phases:

1. The early unplanned, uncontrolled introductions which have usually resulted in species being brought in, disappearing completely, or establishing themselves as residents to become pests causing untold millions of dollars in damage to habitations and crops.

2. Recent introductions based on scientific principles and practices to insure a relative measure of success with a minimum of hazard to the ecology of the receiving area or to its resident species.

According to Phillips (1928), birds apparently were the first interest of early colonists for introduction, although the history of species and introduction to this country is mostly clothed in darkness. However, it seems apparent that even though early America had a wealth of animals and plants there was still a longing for living souvenirs of the old country among the people who came here from the other parts of the world. In addition, the colonists were intensely practical men who recognized that wildlife could help feed and clothe them.

For example, ten years after the Declaration of Independence, George Washington was the recipient of a shipment of foreign game birds. In 1786, his friend, the Marquis de Lafayette, sent him several kinds of pheasants and a pair of French or red-legged partridges, Alectoris rufa. Also, Richard Bache, a son-in-law of Benjamin Franklin, introduced English pheasants, Phasianus colchicus and gray partridges, Perdix perdix, to his estate in New Jersey in 1790. There is no evidence that any spread from these early trials.

Until recently, the introduction of foreign fauna has been haphazard, without attention to the ecological requirements of the species or of their possible adverse effects. As a result, few species have persisted which are desirable. Among those which have become established, some have produced disastrous effects on the existing environment and the economy of the people. A regrettable feature, until very recently, has been a neglect to record the facts, with the result that much of the significance of these introduction experiments has been lost to the scientific record.

BIRDS

According to Phillips (1928), periods of activity in introduction of foreign birds began in the late 1860's. Since then, limited information is available on what was attempted. For a period of 15 or 20 years, unsuccessful efforts were made to introduce species of European song birds, largely through the enthusiasm of German-American bird fanciers and various cage-bird clubs.

In the late 1870's the migratory coturnix quail was the subject of a virtual introduction craze all of which were unsuccessful. Little attention was paid to foreign game birds from then until after the successful introduction of Chinese ring-necked pheasants, Phasianus colchicus torquatus, into Oregon in 1881. This event triggered great enthusiasm for pheasants, and ring-necks of various origins--including Chinese, Mongolian and English--were set out indiscriminately all over the country. From these plantings, large Chinese pheasant populations have built up in the central, northern and northwestern farmland. At the present time, the species has an extensive range in these parts of the United States (Aldrich and Duvall, 1955).

The gray or Hungarian or European partridge came next and has also enjoyed great success from large shipments liberated just before World War I. These have succeeded in the drier, grain-producing farmland of

the extreme north central part of the country after failures elsewhere (Aldrich, 1947).

Fifteen great tinamous, Tinamus major, were brought privately from Guatemala in 1923 and placed on Sapelo Island on the coast of Georgia (Phillips, 1928). Additional ones were taken unsuccessfully to Louisiana. In the first locality, during the same period (Phillips, 1928), curassows and chachalacas were transplanted from Mexico. The chachalacas have persisted to the present time, but the other two species disappeared. New efforts with several species of tinamous native to southern South America are now planned under the present Foreign Game Introduction Program described beyond.

The mute swan, Cygnus olor, an ornamental species imported frequently for city parks and estates, has gone wild from time to time. One colony which seems to be prospering at present is near Newport, Rhode Island. The little European land rail, Crex crex, known as the corn crake was set free by the Cincinnati Acclimatization Society between 1874 and 1877, but was never found again. Guineafowl were liberated in Georgia and California and achieved temporary success in the latter State about 25 years ago, (Phillips, 1928). There are none today.

Black grouse, Lyrurus tetrix, and capercaillie, Tetrao urogallus, two famous birds of northern Europe, have received considerable attention. A large shipment of black grouse was liberated in 1904 and 1905 on Grand Island in Lake Superior. Others were set out in the Adirondack Mountains of New York State about 1900. Capercaillie were released at New Sweden, Maine, in 1895; on Grand Island, Michigan, in 1904 and 1905; in the Adirondacks of New York in 1906 (Phillips, 1929).

Experimental releases of both species were made on Outer Island, Wisconsin, in 1949 and 1950, as a part of the Foreign Game Introduction Program. They did not succeed (Bump, 1963). Hazel grouse, Tetrastes bonasia, were also set out on Grand Island, Lake Superior, in the early 1900's. None of these grouse introductions showed any indication of success.

Interest in the chukar partridge, one of the three foreign game species to become established in the United States, was late in getting started, although five pairs were liberated in Illinois as early as 1893. After 1928, however, interest increased rapidly with numerous trials all over the country until the species became well established in the arid Great Basin foothills in the late 1930's (Aldrich, 1947 and Christiansen, 1954).

The red-legged partridge has received little attention in this country since Lafayette sent the first ones to George Washington at Mount

Vernon, Virginia. A few pairs were imported into Illinois in 1896 but vanished the following spring. Recently, the Foreign Game Introduction Program has included this species for extensive trial in the southern parts of the United States.

The black francolin, Francolinus francolinus, was imported unsuccessfully into Illinois in 1891. In recent years the Foreign Game Introduction Program has given much attention to this species and the gray francolin, Francolinus pondicerianus, and considers them candidates for successful introduction for some areas in central southern parts of this country (Bump and Bump, 1964).

Bamboo partridges, Bambusicola thoracica, have been introduced on a large scale in the arid interior sections of this country beginning in 1904, and have been given a fair trial recently under the Foreign Game Introduction Program. All efforts have been unsuccessful.

Reeve's pheasant, Syrmaticus reevesii, recently was given a thorough trial by the State Conservation Department in Ohio. The results were not encouraging. The silver pheasant, Gennaeus nycthemerus, has been tried unsuccessfully on a small scale in the State of Washington. Kalij pheasants, Lophura leucomelana, have been the subject of considerable study, and as a result are recommended for trial introductions under the Foreign Game Introduction Program. Likewise, the red junglefowl, Gallus gallus, another forest-inhabiting pheasant, studied intensively in India, has been considered a likely candidate for establishment in game-deficient wooded sections of the southeastern United States (Bump and Bohl, 1961).

Golden pheasants, Chrysolophus pictus, have been liberated many times in the country starting with a pair sent to George Washington by Lafayette in 1786. In addition to Virginia, liberation has been in such widely separated places as California, Washington State and Illinois. No success is indicated.

Both the copper pheasant, Syrmaticus soemmerringii and the green pheasant, Phasianus versicolor, of Japan have had limited trials starting in the Northwest about 1885. Recently, the Foreign Game Introduction Program has given attention to both of these species and the green pheasant has shown signs of becoming established in coastal Virginia.

Sand grouse, Pterocles exustus, have been liberated from time to time starting in Washington & Oregon in 1881. Recently, more extensive efforts, under the Foreign Game Introduction Program, have been made but are not encouraging.

Among the doves, the bleeding heart dove, Gallicolumba luzonica, was released around 1924 in the State of Washington, and the European wood pigeon, Columba palumbus, between 1910 and 1913 in a park in New York, both without success. The common domestic pigeon or rock dove has, of course, gone wild in many places even outside cities. The Chinese spotted dove, Streptopelia chinensis, and ringed turtledove, Streptopelia decaocto, have become established in a limited area in southern California, and the latter also in southern Florida.

Among song birds, many attempts at introduction of numerous species have been made mostly for sentimental reasons. The house sparrow, Passer domesticus and starling, Sturnus vulgaris, have been notorious successes. The European tree sparrow, Passer montanus, a close relative of the house sparrow, persists in a small area about St. Louis, Missouri. The skylark, Alauda arvensis and European goldfinch, Carduelis carduelis, have been liberated in many places in the United States and have always disappeared. Very recently the spotted-breasted oriole, Icterus pectoralis, blue-gray tanager, Thraupis virens, and red-whiskered bulbul, Pycnonotus jocosus, have apparently become acclimated in the vicinity of Miami, Florida, after escaping from aviaries.

MAMMALS

Probably none of the terrestrial mammals (except domesticated forms) have been as generally successful as certain game birds and fish. Most introduced mammal species have failed to survive. Of those which did, the majority became destructive and undesirable, such as the house rat, Rattus norvegicus, and mouse, Mus musculus, the mongoose, Herpestes sp. and the nutria, Myocaster coypu. As early as 1889, Dr. T. S. Palmer called attention to the risks involved in introducing such species.

When Captain Cook discovered Hawaii, only one terrestrial mammal was present--the Hawaiian rat, presumably introduced by the Polynesians at an earlier date. Today, at least 15 species of land mammals are living in a wild state on the Hawaiian Islands. These include pests such as the black and Norway rats, and house mouse; feral domestic species including the cat, dog, pig, goat and sheep; and wild exotic species, such as the rock wallaby, Petrogale sp., the European rabbit, Oryctolagus cuniculus, the mongoose, axis deer, Axis axis, Columbian black-tailed deer, Odocoileus hermionus, pronghorn, Columbianus antilocapra americana, and the mouflon sheep, Ovis musimom.

Introductions on the King Ranch in Texas have been summarized by Lehmann (1948). On this and other extensive Texas ranches, various exotic game species have been released on the open range in hopes of their becoming established in the wild. Besides several American species from further north, these introductions have included fallow deer, Dama dama, blackbuck, Antilope cervicapra, nilghai, Boselaphus tragocamelus, mouflon, serow, Capricornis sp., aoudad, Ammotragus lervia, roe deer, Capreolus capreolus, sambar, Rusa unicolor, and axis deer. These efforts are currently being evaluated by the Texas Wildlife and Parks Department.

One of the earliest game reservations in the United States was the 26,000-acre preserve in New Hampshire established by Austin Corbin in 1880 (Manville, 1964), which is still maintained as a game area. Both native and non-native mammals were introduced. Among the non-native mammals introduced there in the early years were European wild boar, Sus scrofa, red deer, roe deer and Himalayan tahr, Hemitragus jemlahicus. Today, only the descendants of the boar and elk, Cervus canadensis, remain.

Conversely, we have furnished muskrats for introduction to Europe, and gray squirrels, Sciurus carolinensis, to England and South Africa, where both have become established and are now regarded as pests. Further, American beaver, Castor canadensis, and mink, Mustela vison, have gone to Scandinavia; raccoons, Procyon lotor, and skunks, Mephitis sp., to Russia; and elk to Austria and New Zealand, (de Vos et al., 1956).

None of the mammals introduced to North America has proven completely successful and desirable from the viewpoint of our present human population. Some have been more destructive and undesirable than others (Manville, 1962).

The brown rat, R. norvegicus, is thought to have originated in Central or Southeastern Asia. This rodent was introduced into the American colonies in 1775 and has since spread to every State. Rats eat millions of bushels of grain each year and carry many diseases.

At the time of the colonization of North America by Europeans, the native red fox, Vulpes fulva, apparently occurred only in what is now Canada, Alaska, and the United States roughly north of Pennsylvania, Between 1650 and 1750 red foxes, for hunting purposes, were introduced from England into Virginia and the country further south. They survived, spread, and apparently crossed with the native red foxes to the north. Foxes are occasional destroyers of poultry and are reservoirs of rabies and other diseases, (de Vos, et al., 1956).

The European and Russian races of wild boar were introduced into New Hampshire in 1889, and into North Carolina in 1912. They have since spread from these original sites. Some of the Carolina stock were later transplanted to California (1924), and to Hawaii, where a total population of 80,000 was estimated in 1964, (Anon, 1965). As game animals they are favored by some sportsmen. However, they do compete with native species, may do considerable damage to local crops, and are subject to cholera and other diseases.

During our Civil War, a number of camels were introduced for possible use by the Army as draft animals. Several attempts were made to establish them in Texas, Cuba, Jamaica and South America; all were unsuccessful, (Goodwin, 1925). The camels introduced into our country survived for many years in our southwestern deserts before finally disappearing.

Between 1891 and 1902, the semi-domesticated Old World reindeer, Rangifer tarandus, were introduced from Siberia to Alaska in an attempt to improve the economy of the native Eskimos. At first they thrived and increased, but then declined. Their history in Alaska has been erratic owing largely to a lack of knowledge of proper management procedures. In 1929 a herd of 2400 was sold to Canada, and the offspring of this herd still persist, providing food for the native peoples and thus aiding in the economy of our northern areas. They also have competed with, and tended to hybridize with, the native caribou. Disadvantageously, they damage the delicate Arctic range considerably by overgrazing.

Fishes

With the exception of aquarium fishes, very few exotic species of fish have been brought into the United States. About 1,200 to 1,500 aquarium species have been imported from Africa, Ceylon, China, Germany, Japan, Malaysia, and Central and South America. Only a few of these species have become established in our natural waters, (Swingle, 1957).

Deliberate fish introductions for the purpose of improving our fishery can be divided into three different periods:

1. Before 1887. During the 1870's, prior to the organization of a Federal agency and various State fish commissions, fish were brought into the United States by private individuals. Although many native species of fishes were transplanted to other sections of our country during this early period, only a few non-native species were imported. These probably included the European carp and the goldfish. None of these introductions were particularly successful.

2. 1877--1900. During this period, introductions of foreign fishes were mostly the results of cooperative ventures of Federal and State fishery agencies. During the first few years of operation the U. S. Fish Commission encouraged and assisted the States in organizing State fish commissions. Early efforts of Federal and State fish commissions were concerned with transplanting native species and developed fish culture facilities. Around 1875, attention was given to the possibilities of foreign fish introductions. During the following 25 years, several species of fish were imported including the European carp and the brown trout.

3. 1954--Present. As a result of the overwhelming success--with rather disastrous results--of the planned introduction of the European carp during the period from 1879 to 1896, Americans developed a great apprehension concerning foreign fish introductions. This feeling persists even today. Within the past 10 years, however, fishery biologists and some sportsmen have considered the importation of foreign fishes which might improve our sport and commercial fisheries. A few species, such as some of the tilapia, have been successfully introduced in selected waters. The early fear still exists and elaborate precautions are taken before any foreign fishes are deliberately released in natural or impounded waters.

The following is a brief account of most of the foreign fish introductions into the United States:

The two most highly successful introductions were the European carp and the brown trout.

The carp (Cyprinus carpio): It is uncertain when the first carp were brought to the United States. It was reported (Cole, 1905), that Captain Henry Robinson, Newburgh, New York, brought carp from France in 1831 and 1832, and that he stocked some in the Hudson River.

Mr. J. A. Poppe, Sonoma, California, brought carp from Germany to California in 1872. Professor Spencer F. Baird, Commissioner of the United States Fish Commission (Cole, 1905), questioned whether or not these were true carp.

Mr. Rudolph Hessel shipped 345 carp to New York on May 26, 1877, and these were taken to ponds in Druid Hill Park, Baltimore, Maryland. During the spring of 1878, 113 carp were transferred from Baltimore to ponds on the Washington Monument lot in Washington, D. C. During 1879, 12,265 carp were distributed to over 300 persons in 25 States and territories. During 1883, 260,000 carp were distributed to 9,872 applicants in 1,478 counties. By 1897, carp culture was discontinued by national fish hatcheries.

The primary purpose of importing the carp was to provide a food fish for our growing population. Some of the advantages of the carp were reported to be:

1. Their high fecundity and adaptability to artificial propagation.
2. They lived largely on a vegetable diet.
3. They were hardy.
4. They were highly adaptable.
5. They grew very rapidly.
6. They were harmless in relation to other fishes.
7. They populated waters to the fullest extent.
8. They were an excellent table fish.

Carp lived up to some of these expectations. Their fecundity and ability to populate waters was demonstrated in Lake Erie. A few carp were stocked in western Lake Erie in 1883. By 1889, commercial fishermen took 3,633,679 pounds. The carp sold for about one and a half cents per pound. Coincidentally, there was a major decline in aquatic vegetation, particularly Vallisineria, Sagitteria and Zizania.

There was also a decline in the canvasback duck (Aythya valisineria) population in western Lake Erie. By 1900, most of the desirable aquatic vegetation was gone as were the canvasbacks. Similar reports were received by the U. S. Fish Commission from duck clubs throughout the United States. There were also reports of serious declines in game and commercial fishes. Although glowing reports on the high food value of the carp were received by the U. S. Bureau of Fisheries from carp recipients, the American public did not accept the carp as a table fish.

The European carp, whether good or bad, had found a home in America. By 1904, it was found in great abundance throughout the country. Thousands, perhaps millions, of dollars have been spent in attempting to eliminate this species from certain waters. Except for small ponds, these attempts have been only temporarily successful.

During the past few years, the Israeli strain of the European carp has been used successfully in controlling vegetation in some farm ponds in the southeastern United States (Neely, et al., 1965). It is reported that this strain does not reproduce in ponds nor does it compete with largemouth bass, Micropterus salmoides and bluegill, Lepomis macrochirus.

During 1962, commercial fishermen took over 30 million pounds of carp. The average wholesale price was about 3½ cents - per pound.

The brown trout (Salmo trutta): In many American trout waters the brown trout is highly prized as a game fish. It is also highly regarded as a table fish.

The first brown trout were reared in the United States by Mr. Seth Green of the New York State Fish Commission in 1883. About 30,000 trout were hatched from eggs received from Herr von Behr of Germany. The following year, Loch Leven eggs were received from Scotland (Marston, 1896). By 1900, brown trout had been widely distributed in American trout waters through efforts of State and national fish hatcheries. The various subspecies of European brown trout have lost their identity in America and they are all considered to be one species. Although brown trout propagate naturally in many American waters, much of the fishery is maintained through artificial propagation and stocking. Over 1,000,000 pounds of brown trout are reared annually by State and national fish hatcheries.

The major complaint received from sport fishermen concerning the brown trout is that they are more difficult to catch than the native trout. The main advantage of the brown trout is that they can tolerate warmer waters than most native trouts.

In addition to the carp and brown trout, several other species were brought into the United States during the 19th century. These include:

1. Danube salmon (Danube trout), Salmo hucho: Mr. Thaddeus Norris, a New York fish culturist, obtained Salmo hucho eggs in 1864. Although the eggs hatched, the liberated fry did not survive, (Baird, 1874). Our Division of Fish Hatcheries is interested in this species. However, its habitat requirements and disease characteristics must be established and determined before further introductions into this country can be accomplished.

2. Goldfish (Carassius auratus): Captain Henry Robinson of Newburgh, New York, stocked goldfish in the Hudson River in 1843. During the past 100 years almost every American household has had one or more goldfish as pets at one time or another. These are usually kept in bowls, aquaria and outside garden pools. Many goldfish have found their way to natural waters via kitchen sink drains or by the overflow of garden pools. They are found in natural waters throughout the United States, but are rarely found in large numbers. They are commonly cultured as bait minnows. This species rarely reproduces in farm ponds and is the only recommended bait minnow for farm pond use in some of the States. Nevertheless, several hundred thousand pounds are taken annually by Lake Erie commercial fishermen.

3. Tench, Tinca tinca: The tench was introduced from Europe late in the 19th century as forage fish. Although it has been widely stocked it has only survived in a few waters, without any noticeable ill effects on the native fish fauna or habitats to the present time.

4. Golden orf, Idus idus: This species was also introduced from Europe around 1894, and although it was widely stocked, it has never done well in our natural waters.

5. Bitterling, Rhodeus sericeus: The bitterling was introduced into the United States around 1925 and is apparently established in one stream, Sawmill River, in New York (Moore, 1957). No ill effects have been noted, although the fish may have established a form of commensal relationship with molluscs in the stream.

In addition to the preceding, during the 20th century several species of fish were brought into the United States for experimental purposes. These include several species of Tilapia. Tilapia mossambica were brought to Hawaii from Singapore in 1951. This species is well

established in ponds and reservoirs on the major islands of the Hawaiian group where they are utilized as food fish. Tilapia are also used in the Island area as a bait fish for the skipjack tuna, Euthynnus pelamis, (Hida et al., 1962). Although Tilapia were previously brought into our country as aquarium fishes it was not until 1954 (Swingle, 1960), that experiments in using members of this genus as pond fish in the Southern States were begun at Auburn University in Alabama. Tilapia are usually overwintered inside hatchery buildings. The fry are stocked in the spring when water temperatures reach about 60 degrees Fahrenheit. Excellent success has been obtained in the production of Tilapia as a pond fish. The most common species used are Tilapia mossambica, T. nilotica, and the Malacca hybrid of Tilapia. In southern Florida, Tilapia have overwintered out-of-doors. One African species, T. heudeloti (Synonym T. macrocephala), apparently escaped from captivity and is well established in the Hillsborough Bay area on the west coast of Florida (Springer and Finucane, 1963). At present it is a rather aggressive, but not destructive, addition to the aquatic fauna of the area.

Other species which were recently imported for experimental pond and lake use include the grass carp, Ctenopharyngodon idellus, obtained from Southeast Asia, the peacock bass, Cichla ocellaris, from South America, and the Ohrid trout, Salmo ohrid, from Yugoslavia.

The South American suckermouth armored catfish, Plecostomus sp., was found in the San Antonio River, San Antonio, Texas, in 1964, (Barron, 1964). They apparently escaped from a pool in the San Antonio Zoo where they were stocked in 1956 to control filamentous algae. This area of the river is fed by warm springs, and winter water temperatures are slightly above the 62° F. limit for this fish. The piquito, a poecilid, Belonesox belizanus, a native of Central America, is also found in the same section of the San Antonio River.

Several imported aquarium and bait fishes have become established in limited areas. These include the Oriental weatherfish (dojo), Misgurnus anguillicaudatus, which was found in a Michigan pond (Schultz, 1960). It was reported (Deacon, et al., 1964) that convict cichlids, Cichlasoma nigrofasciatum, were established in Lake Mead and other areas in Nevada. Other foreign species recently found in Nevada are guppies, Lebistes reticulatus, shortfin mollies Mollinesia mexicana, and platys, Xiphophorus maculatus. Mollies have also become established in parts of Florida.

For the most part, these introduced species are limited to their distribution by finding their required habitats only in scattered, isolated areas. Within these confines, the exotics have restricted their diets to small aquatic organisms and have not been overly destructive or competitive to the present time.

Amphibians and reptiles

In addition to the introductions of birds, mammals and fish described in this paper, there have also been introductions of amphibians and reptiles. These have probably been accidental and none can be said to have been the result of biological study. Many go unnoticed and perish. Some may exist for a time, but few have survived to become a part of the animal community in which they were released. Snakes and lizards often escape from traveling zoos and animal shows. Tropical varieties usually do not survive the first winter in a temperate or cold climate. Also, chances of the two sexes meeting in the strange environment are even more remote. Possibilities of exotic species surviving are much better in southern latitudes and a number of amphibians and lizards are reported as occurring in the State of Florida resulting from chance introductions.

Consultation with specialists of the United States National Museum, reveals that some 14 species and subspecies of lizards have found their way to Florida's mainland and now seem to be established there. Several of these were originally found in the Caribbean area. Also, four amphibians, principal of which is Bufo marinus, the marine toad, have become established in Florida. This species is giving herpetologists some concern because it is highly competitive with our native frogs and toads and appears to be reducing the number of some beneficial species.

THE MODERN PROGRAM

Recent and current programs have been designed primarily to augment the natural stocks of game animals in the United States, particularly birds. Although America has always had a rich outdoor legacy, originating in early colonial days, the demand for recreation through fishing and hunting has grown tremendously.

Nationwide surveys of hunting and fishing conducted in 1955 and 1960, show the scope and magnitude of fishing and hunting in America:

> "A detailed study of participation in these sports, including types of fishing and hunting, expenditures, mileage traveled and the like, was made of the more active sport fishermen and hunters, who for the most part, were licensed or, if unlicensed, either took part in these sports on several occasions or reported at least a modest expenditure for these activities. This study--the NATIONAL SURVEY OF FISHING AND HUNTING--revealed an estimated 30 million sport fishermen or hunters in 1960, some 23 percent of the population 12 years old and over. These more substantial

participants reported around 650 million recreation days of fishing and hunting and an expenditure of close to 4 billion dollars on these pastimes. As compared with a similar survey conducted in 1955, the number of these sportsmen had increased by over 5 million and their expenditures by 1 billion dollars."

The preceding illustrates the interest in these sports by the American public and also shows the role they play both personally and economically in the lives of a large portion of the population.

As the responsible federal agency, the Department of the Interior, Bureau of Sport Fisheries and Wildlife, is vitally concerned with introductions of foreign fauna for several reasons. We are obligated to protect our citizens against harmful effects on existing natural resources by unplanned foreign introductions, and on the other hand, to supplement these resources with desirable additions from abroad. We recognize the fact that this is a difficult ecological problem.

A growing awareness is developing that attention must be paid to all aspects of proposed actions affecting natural resources, particularly those involving subtle biological effects.

This awareness was slow in starting. Unfortunately, in the economic and intellectual growth to our present status there were many mistakes involving exploitation of plants and animals. Since the colonists first arrived, our country lost the passenger pigeon, the heath hen, the Carolina parakeet, the sea mink and many others--all bitter commentaries on a failure to understand the importance of conservation practices.

Today, the conservation movement is stronger in our country. Once again, we can see the bison, the whooping crane, the trumpeter swan, the sea otter, the fur seal and other species that were brought to the verge of extinction -- but saved. For them, conservation consciousness came in time and they survive through good management and understanding of their ecological requirements.

We must contend with many factors resulting from constantly changing land use. Our population is increasing very rapidly and land, formerly providing habitat for certain species, is being converted into great urban areas. The so-called "clean farming" with new types of farm equipment, heavy grazing, and chemical control of weeds all cause changes which may not meet the needs of the native fauna. Thus, species which thrived under one set of environmental conditions may not survive when these are changed. Consequently, there is a decrease in game abundance and, in some instances, of the species withdrawn from the former range. One example is the prairie chicken, formerly resident over a large area from the North Central States south to Texas.

Initially responding favorably to very limited and primitive farming which first invaded its native grasslands environment, it declined drastically after overgrazing and use of its range for modern agricultural purposes, and occasional over-hunting.

There are large areas in the United States which have never been occupied by more than one or two species of game birds and, in some cases, none at all. We have focused our attention on these regions. One example is a large part of the arid West that was sparsely stocked with native game birds until the chukar partridge was introduced. Now, in this region, excellent upland game hunting is available since the chukar has survived as a successful resident in some of the arid rim rock and foothill country.

In general, (McAtee, 1929), it appears that the wildlife of the Old World has shown far greater ability than that of the New to survive despite man's occupation of the land. It is logical, therefore, when seeking species for transplanting to a well populated country to utilize those species that have been tested and tempered by countless centuries of close association with man.

We recognize the hazards in introductions and have attempted to avoid them while also trying to meet the demands for additional wildlife resources in certain areas. We have established certain criteria that must be considered before a candidate species is released into the wild. Questions which must be satisfied, include:

1. Does a niche occur in a particular environment that is devoid of a native species?

2. Is there a habitat type in which native species are not sufficiently abundant to provide reasonable harvests?

3. Do habitats exist which have been modified by agriculture and other human activities to the point that they can no longer support native species?

4. Will a species threatened with extinction in its native range find a similar and suitable habitat in a different geographic area without posing a threat to native species already occupying that habitat in the new area?

In the past, candidate species for introduction have been sought and their characteristics assessed for value in supplying additional hunting recreation. Another conceivable objective has received some attention: Use of the Introduction Program to assist in the preservation of rare and endangered species. The great upsurge of the public's consciousness over its responsibility for preventing any more species from becoming extinct gives greater emphasis to this objective.

A special concern is the effects of introductions on the ecology of various environments in which the new species are to be tried. We evaluate ecological-niche relationships of both existing and candidate species to determine their similarities and differences, and to provide a basis for estimating the effects of introductions on the native fauna. We are aware that a new species may serve as a reservoir for new diseases or parasites detrimental to native species, and that it may offer serious competition to native species or possibly be a predator in the new environment. Lastly, and not the least important, will it, because of possible close genetic relationship, interbreed with a native species, thus upsetting the genetic adaptation to its environment acquired through many generations of natural selection?

Economic implications must be carefully considered. The exotic starling and house sparrow do millions of dollars worth of crop damage each year, and the domestic pigeon or rock dove, has gone feral and become a pest. In our cities, all three birds foul public buildings, and their droppings are loci for diseases which affect humans.

Game production habitat in the United States is decreasing under the impact of human activities such as clean farming, scientific forestry, overgrazing, drainage, pesticides, declining soil fertility, and urbanization. All contribute to a decline in the abundance of native game birds and limit their distribution.

We conducted a survey (1955), through game departments in the fifty States who reported on the amount, distribution, types and characteristics of understocked habitats. The results indicated that over one-fifth of the land area of the United States is understocked with game species. Some areas had no native game birds. In others, game bird populations were very low.

For the Foreign Game Introduction Program these are the target areas. They afford the possibility of locating and introducing an adaptable exotic game bird that might thrive without creating serious problems for man or the resident wildlife. There are limited risks involved, but there are also very substantial rewards. For example, in a normal year our hunters harvest 50 million game birds, including 10-12 million pheasants, 4 million gray (Hungarian) partridges, and 1 million chukars. These provide nearly thirty percent of the total game bird harvest. As far as has been determined, none of the three are incompatible with native species. Also, the first two are tolerant of agricultural practices and the third inhabits an area where only a scattering of native game birds is found. Without them, there would be substantially less recreational hunting in the United States.

Our program is particularly concerned with birds. It is known as the Foreign Game Introduction Program. It originated in 1948 and has two objectives:

1. To discourage unwise game bird introductions by making careful biological evaluations in advance of any importations.

2. To meet a real recreational need by filling vacant niches with attractive, adaptable game species.

This program is a cooperative effort between the various State game departments, the Federal government, and a private concern, The Wildlife Management Institute.

Studies are made to define world analogues for continental United States areas, and candidate game species are selected. We perform on-the-spot study of habitats, characteristics and requirements of candidate species, and coordinate this with State game departments for trial consideration. Biologists are assigned overseas to select the candidate species. We require intensive study in the foreign country to define the habits, habitats, hazards and potential of the species, particularly with regard to its chances of survival in the United States without competing unduly with existing native species or becoming a pest. Finally, it is necessary to secure, ship and quarantine adequate numbers of birds for field release with cooperating States in habitats believed to be suitable.

Since 1950, more than 100 varieties of foreign game birds have been considered. Of these, 18 have been selected for intensive study before trial release in 45 States.

Thus far in the appraisal of overall program results, there have been indications of both success and failure. In addition to the two Iranian pheasants already mentioned, black and gray francolins have demonstrated an ability to survive, reproduce and increase in release areas. Conversely, the Indian sandgrouse, Pterocles exustus hindustan, and Reeve's pheasants have not succeeded. Six other species are holding their own sufficiently to justify guarded optimism.

Progress in the studies of the candidate species in their native lands, the gathering of stock of promising exotics, and the propagation and liberation of stock of the chosen species by the cooperating States has been described by Bump and Bohl (1964), Bump and Bump (1964), and Christensen and Bohl (1964).

The unplanned, hit-or-miss character of almost all of the early introductions was the prime reason for their failure. The people who desired to acclimatize the foreign species to our shores did not have the scientific acumen to fully evaluate differences in climate and habitat between their old and new countries. Many species were introduced into areas completely different from their original homes, with the result that they failed to "take" and disappeared. Also, the long periods required for sea transit without necessary fresh foods and proper caging caused animals and birds to arrive in a weakened physical condition, thus reducing their chances of survival.

Recently, an additional facet became apparent in foreign introductions: There exists within a species variant populations or subspecies which have differing transplant capabilities. For example, the subspecies of ring-necked pheasant from northern China, which was so successful in the northern United States, failed in our southern States despite numerous attempts; however, the subspecies from Iran has been tried in Virginia and gives strong indication of being successful.

Dr. Gardiner Bump, biologist in charge of our program in Argentina, has listed reasons for the possible failures of promising candidate species. These can be summarized as follows:

1. Failure to liberate in the proper habitat or failure to use proper methods in liberations.

2. Poor physical condition of the liberated game precluded survival.

3. Failure to properly condition game farm raised birds before liberation.

4. Failure to release sufficient numbers of specimens to ensure a breeding potential over a period of time.

5. Failure to ensure protection in losses resulting from predators or hunting pressure.

In addition, the time that is required to assess the success or failure of an introduction activity is often not realized. Thus, success of a program may entail as much as five to twenty years before an evaluation can be made regarding any specific species. We know the ring-necked pheasant required years and many tries before it finally "took." For this reason, we have, perforce, been guarded in our statements regarding our efforts.

The program has been successful in that many of the fears of critics have been proven to be groundless. None of the candidates released have usurped the normal ranges or habitats of native species, nor have our releases brought into the country game diseases which were disastrous to native species. Further, there has not been any widespread hybridizing with resident game to the disadvantage of native populations. Our experiences have demonstrated that ecological dovetailing into the prospective habitat has been the major factor in success of our activities.

From its start the program has been controversial. Some look on efforts with exotics as unnecessary and unwise. Also, there is the aesthetic objection to mixing foreign and native faunae. And, in addition, there is the more practical concern about adding foreign forms of life without knowing the biological and economic consequences.

On the other hand, many parts of our country have changed irreversibly as a result of human population movement and consequent agriculture and industry. In these, resident native species have become extirpated because they were intolerant of habitat changes. The foreign introduction program takes cognizance of this and seeks to bring in species that can exist in such areas, succeed and become established.

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