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MIGRATING EELS IN LAKE ELLESMERE

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Introduction: Little detailed information has been recorded concerning the autumnal seaward migration of eels from New Zealand rivers and lakes. It is well known that two species are involved: the short-finned eel (S.F.) *Anguilla australis schmidtii*, and the long-finned (L.F.), *A. dieffenbachii*. Hefford (1934), in respect of Lake Onoke, and Cairns (1942), as regards Lakes Onoke, Forsyth and Ellesmere, described accumulations of eels which occurred when passage seawards was impeded by shingle bars, and gave the general period of arrival as from February to May, and the sequence of arrival as S.F. ♂, S.F. ♀, L.F. ♂, and L.F. ♀. The observations recorded here were made in 1942, when an acute shortage of fish oils threatened to hold up certain industries and made it desirable to learn something of the quantity and qualities of eels available at Lake Ellesmere.

Lake Ellesmere is a shallow lagoon of roughly 100 sq.m. in area, and lies west of Banks Peninsula. Its extent increases as the inflow from tributaries inundates farm lands. Maximum depth is usually less than 8 ft. Towards its southern extremity the lake is separated from the Pacific Ocean by a narrow bank of gravel. The narrowest part, through which water percolates and over which waves occasionally break, is opposite Taumutu village, about half a mile from the southern extremity. It is here that from time to time an outlet is cut. A French chart, dated 1848, in the Canterbury Museum shows an outlet at the southern extremity, with a statement that the lake is opened periodically by the Natives for the taking of eels. The old and recent outlet points are connected by a deep, weed-grown arm of approximately 800 x 100 yd., at the head of which a small stream enters from a quagmire. In the immediate vicinity of the outlet beach, and north-west for a few miles from it, the bed of the lake is mainly firm, without deep mud or weed-beds.

In 1942 the lake remained closed until June 7. The level was low at the beginning of March and water percolated through the bank as the tide rose and fell. As the level rose, the relative duration of outflow to inflow increased until the latter part of May, when no further inflow of salt water was apparent. Temperatures of lake water fell from 64° F. in early March to 56° F. early in April, to 50° F. by May 1, and had dropped to 39° F. by June 7. The weather was very stormy in March and abnormally mild in April and early May.

Times and places of observations: Visits were made to the outlet beach on March 12, 24, 25, and 31; on 54 nights between April 5 and June 9 observations were made at the outlet beach, and usually also in the weed-grown southern arm and the creek entering it. The 500-yard-long portion of the outlet beach where eels congregated after dark was the narrowest and most permeable part of the barrier between the lake and sea. In March, but not later, lesser numbers of eels were present after dark in marginal shallows on the seaward side of the weedy southern arm. At most times, when eels collected at the outlet beach, concentrations of migrants were also observable in the creek at the head of the arm. At such times, no migrant eels were observed on occasional visits to Ludimann's Drain and Hart Creek, the two next nearest tributaries. At distances beyond two miles north from the outlet beach no migrants were observed inshore at night.

Size and appearance of migrant eels: A sample of 69 S.F. ♂ ranged in length from 15 to 23 in. Mean length 18.9 in. Mean weight 0.44 lb. 253 S.F. ♀ ranged in length from 22 to 32 in., mean 27.1 in., mean weight 1.24 lb. They were thus about three times as heavy as males. Three exceptional fish of many thousands seen were: 40.5 in., 4.5 lb.; 41.0 in., 5.75 lb.; 42 in., 5 lb. Ovaries varied somewhat in degree of development, but were always recognisable as such. Gonads of males were only sometimes sufficiently developed to be recognised by the naked eye.

Migrant S.F. eels were distinguishable by their greatly enlarged, slightly pointed, black or black-fringed pectoral fins, by enlargement of the eyes and reduction of the lips, and by the extension of reddish-black shades into the inside of the mouth. Usually sensory pores on the lateral line and on the head were much more conspicuous on migrants. Copper and pale-greenish shades tended usually to be replaced by grey.

A sample of 51 L.F. ♂ ranged in length from 22.5 to 29 in., mean 25.4 in. Mean weight 1.4 lb.

L.F. ♀ ranged in length from 32 to 54 in., mean 47 in.; mean weight 13.2 lb.; approaching ten times that of males. Of 177 females, all except 37 were in the 43–50 in. groups. Only 24 fish were outside the limits of 10–19 lb. No change in the size of L.F. ♀ was apparent as the run progressed, and local fishermen stated that the size in 1942 was not abnormal. Their weight at migration was about three times what Cairns (1942) considered usual for the main run, although he considered that a later run of larger fish occurred. Because of the fish-eating habits of the L.F. ♀, the question of usual size attained before migration is of importance.

Gonads of L.F. ♂ varied in degree of development, but were always distinguishable by naked eye. Ovaries appeared much more uniformly developed; those removed from a sample series comprised 10% of their gross weight.

L.F. ♂ were distinguishable from all other eels handled because they alone felt soft and "flabby." In colour they were a soft sooty black, becoming pale on the ventral surface, where often dark blotches spread irregularly over a dirty-white field. Black shadings were intensified on the margins of the pectorals. Heads appeared somewhat flattened, eyes were enlarged, and black shadings extended into the mouths. L.F. ♀ lose their fleshy lips and the large muscular dome from the top of the head, which fines down and becomes very dark with black extending into the mouth. The general body colour is black, or dark chocolate, relieved by grey or white on the ventral surface. Because no L.F. ♀ intermediate in appearance between migrants and non-migrants were taken, it is inferred that they seek cover when they metamorphose.

Quantities of eels: A method frequently employed in fisheries science was used to estimate quantities of eels which congregated in the vicinity of the outlet beach. This involved the marking of a known number of fish, the release of the marked individuals to mix with the bulk of the stock, and the determination of the proportion of marked individuals in the stock, and then by a simple calculation an estimation of the total number.

Between April 6 and 19, 2,000 S.F. migrants were marked by removing with scissors a portion of the right pectoral fin. Fish appeared to swim normally after this operation, and no dead or distressed fish were encountered subsequently. Later, 3,420 S.F. migrants were captured and examined. Of these seven had been marked. Three were taken in the first 1,054, and three in the final 1,223. The latest recapture occurred 14 days after marking ended, and later only 266 fish, all unmarked, were captured. These data suggest a total of about 977,000 S.F. migrants, which, at an average weight of 1.14 lb, would represent about 500 tons.

Between April 25 and May 7, 510 L.F. ♀ migrants were marked by cutting off a small piece of the dorsal fin. Subsequently, until June 7, 544 were killed and found to include 72 marked individuals. This suggests a total of 3,850 fish, weighing about 23 tons. No estimation of the quantity of L.F. males was attempted. The progressive reduction of the permeability of the bank as it broadened with storm action may have been less favourable to the congregation of L.F. eels than S.F. eels. No significant change of ratio of marked to unmarked fish occurred between May 7 and June 7 to suggest that the congregation of L.F. eels was continuing.

Behaviour and distribution of eels: Most eels were taken by the old Maori method of cutting blind channels part-way across the narrowest part of the barrier towards the sea. Eels enter these freely at night. Change of level of the lake, and storm damage to channels, made impossible the maintenance of any standard catching device. Except occasionally when waves broke over, a few L.F. females were the only migrants seen at the beach in daytime or taken there with nets by day. At about dusk the eels approached the surface in the weed-grown arm. In brightest moonlight they tended to remain there, while on dark nights, and especially from two to three nights after full moon, they proceeded to the outlet beach, where they massed densely in marginal shallows. The number of eels which passed within 20 ft. of the shore on the way from the weedy arm of the beach was found on certain nights to range from 150 to 700 fish per hour, and to continue at that rate on occasions for upwards of eight hours. Many more eels passed further offshore. This movement was always irrespective of the direction of the wind. North along the barrier from the beach a limited "trade" of eels occurred inshore, and was usually with the wind. At the beach the number of eels in the extreme margins and in the channels was greatly conditioned by the tide. Fish were repelled when salt water percolated in through channels, although they would attempt, always without success, to swim or climb up if waves broke over. A strong outflow on dark nights usually induced the greatest entry into channels.

Changes in composition of stock of migrants: S.F. migrants were present at the outlet beach in large numbers on suitable nights from at least as early as March 12 until the end of April. On April 22 a sample of 250 showed a ratio of 1 ♂ : 7 ♀. Numbers fell rapidly during May, and migrants of this species had almost completely disappeared by June without escaping to sea.

No L.F. migrants were positively identified, or taken in channels, at the beach until April 8, when the first males appeared, to be followed four days later by females. At all periods females outnumbered males. The ratios of males to females were as follows: April 8–30, 1 : 1.1; May 1–15, 1 : 9.5; May 16–June 7, 1 : 66.0.

In the same three successive periods, the ratios of L.F. migrants to S.F. migrants in channels at the beach were 1 : 30.3, 1 : 1.9, and 1 : 0.07. On the night of June 6—7, when the lake was first open to the sea, 109 eels were taken, all L.F. ♀.

In the creek draining from the quagmire to the weedy arm, S.F. eels were overwhelmingly predominant in the first period; samples taken in the second period showed a ratio of 1 L.F. : 2 S.F. In the third period, however, the ratio changed remarkably to 1 L.F. : 3 S.F. L.F. ♀, which in the second period had comprised 30% of all fish there, fell to 5%, and males of this species became four times as numerous as females. Consideration of these ratios, and those at the outlet beach, and impressions of directions of movement in the creek (earlier downstream, later upstream), and the almost complete disappearance of S.F. eels and L.F. males from the outlet beach led to the conclusion that these fish finally abandoned attempts to escape, and hibernated.

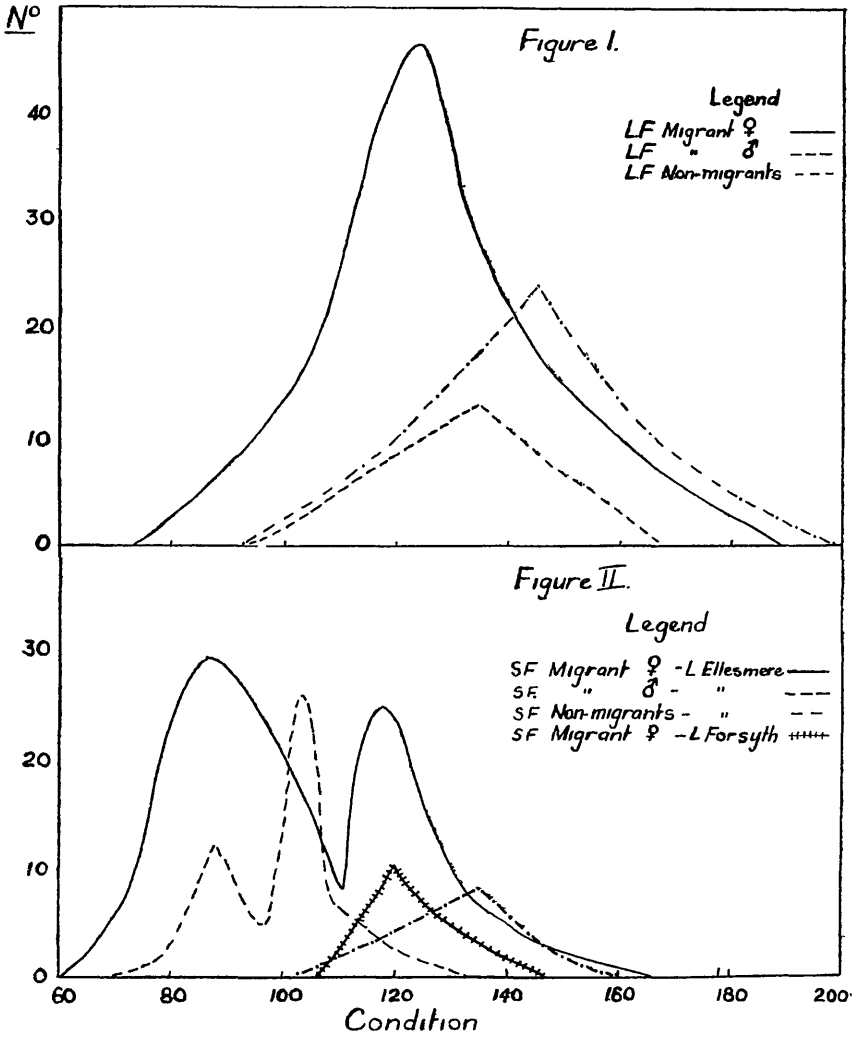
If this happened in 1942, had it also happened in earlier years, and were the fish seen in 1942 a mixture of several migrant year-classes? Records made available by the Ellesmere Land Drainage Board show that in 1941 the lake was first open for five days from April 26 and later for thirty-six days from August 21. In 1940 it was open only once, for twenty-one days from June 5.

Condition of fish: It is stated by fishermen at Taumutu that in some years large extremely attenuated L.F. eels, with corrugations in the skin on the ventral surface, are taken at Ellesmere, and that migrants sometimes include a proportion of these so-called "stockwhip" eels. Only one such fish was reported captured during my stay there. Two L.F. ♂ of normal size were exceptionally thin, and had longitudinal folds of skin on the ventral surface. S.F. migrants differed very strikingly in condition, but no wrinkling of the skin was observed. S.F. migrants in the nearby Lake Forsyth were much larger fish, but exhibited only a normal range of condition. Groups of non-migrant L.F. eels of the length ranges of male and female migrants respectively, and a group of non-migrant S.F. eels, all from Ellesmere, appeared normal in condition.

The condition factor for individual fish was obtained by dividing the weight of each individual by the cube of its length. For convenience of expression figures so obtained were multiplied by 1,000,000. The results for different groups were as follows:—

Group	Place	No.	Condition Factor Range	Mean
Migrant L.F. ♂	Ellesmere	49	97–163	130
Non-migrant L.F. 14–29 in.	„	69	113–193	147
Migrant L.F. ♀	„	177	77–187	127
Non-migrant L.F. ♀ 32–49 in.	„	31	95–191	139
Non-migrant S.F. eels	„	36	107–155	131
Migrant S.F. ♂	„	69	74–129	(bimodal)
Migrant S.F. ♀	„	253	64–165	(bimodal)
Migrant S.F. ♀	Forsyth	30	112–140	124

Two L.F. ♂ with skin folds had condition factors of 80 and 81 respectively. These two specimens were ignored. The balance of the material in that group can be plotted as a symmetrical curve. All other groups, with the exception of the two sexes of S.F. migrants from Ellesmere, tend to balance symmetrically. The S.F. ♂ and ♀ give bimodal curves. Data relating to L.F. ♂ and ♀ migrants, and to non-migrants of this species from Ellesmere, are plotted in Fig. 1. As



no progressive change in condition with increased size of L.F. non-migrants is apparent, these groups, separated above, are combined in Fig. 1.

Data relating to S.F. ♂ and ♀ migrants and to non-migrants from Ellesmere are given in Fig. 2, with comparative data on S.F. ♀ migrants from Lake Forsyth.

As regards S.F. migrants in Ellesmere, approximately 64% of the females fall in the lower of the two groups indicated, which suggests that more than one migrant class from earlier years may have survived. As regards males, only 33% fall in the lower group. The poorer representation of males of earlier migration classes is probably attributable to the exigencies of sampling. It appears improbable that S.F. eels, which attempted to escape in the autumn of 1941, availed themselves of the opportunity when the lake opened for thirty-six days the following spring. The absence of abnormalities of condition among the L.F. ♀ suggests that any of these fish which failed to escape in the autumn of 1941 either escaped in the spring of that year or died.

Acknowledgment.

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AN UNUSUAL TYPE OF WEB CONSTRUCTED BY A SAMOAN SPIDER OF THE FAMILY ARGIOPIDAE

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THE spider whose peculiar web is to be discussed is one of the most conspicuous of the spiders of the island of Upolu, Western Samoa. It has not yet been possible to identify it, but it appears to belong to the subfamily Araneinae.*

Each web consists of a wide-meshed tangle of threads in the middle of which is suspended a flat dome; in a large web 8–10 in. in diameter. The dome is composed of a thread running in a very close spiral and attached to numerous threads radiating from the centre. The radial threads branch, so that the meshes are much the same size all over the dome, measuring roughly 2 × 1.5 mm. No part of the web is constructed of sticky silk.

In spinning the web the spider first constructs the large tangle. It then clears a space in the middle and begins to put in the radii, outlining a very obtuse cone. It spins the spiral from the centre outwards, circling steadily round below the sheet with its head towards the centre and the legs on the forward side bent and moving rapidly, the impression produced being that of a sewing machine. At frequent intervals new radii are inserted. The spiral thread is attached along a short length of each radius so that when closely examined the thread has a slightly notched or zig-zag appearance. While spinning is going on the sheet is attached only by the apex and margins. When completed, a process taking two or three hours, the spider attaches some vertical threads below the sheet. Then it moves to the upper side, slackens the sheet by cutting most of the threads at the apex, and finally spins a fine-meshed tangle between the sheet and the main tangle, working from the centre outwards. This pulls the conical sheet into the final dome or saucer shape. The resting position of the spider is upside down beneath the dome.

The whole web may be up to about two feet across. Frequently many of all sizes are attached to one another and fill quite large volumes of space. One mass which was observed covered an area at least twenty feet across and extended some twelve feet up trees and bushes. It contained at least 200 large spiders. The small males and several other species of spiders are also found in these webs, some parasitic in that they eat the young and small prey of the large spider. The females lay their eggs in plano-convex brown coccoons hung

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* The spider is *Cyrtophora moluccensis* Doleschall. I am indebted to Dr. Willis J. Gertsch, of the American Museum of Natural History, for the identification.