Lake Tanganyika Fishery Research and Development Project

MOVEMENTS OF PELAGIC FISH IN LAKE TANGANYIKA

by

D. W. Chapman
H. Rufli
P. Van Well
Z. Ndugumbi

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Kigoma, TANZANIA

July, 1976
movements of pelagic fish in lake tanganyika

by

D. W. Chapman
H. Rufli
P. Van Well
Z. Ndugumbi

food and agriculture organization of the united nations

kigoma, tanzania

july, 1976
CONTENTS

CHAPTER 1: INTRODUCTION

CHAPTER 2: METHODS
2.1 Indicators of Fish Movement
2.2 Fishing Methods
2.3 Extensive Fishing In October 1974
2.4 Acoustic Surveys
2.5 School Tracking
2.6 Layer Delineation

CHAPTER 3: RESULTS
3.1 Sequential Ring-Net Catches
3.2 Composition of Ring-Net Catches
3.2.1 Correlations Between Luciolates & Stolothriessa
3.2.2 Correlations Between Lates & Stolothriessa
3.3 Catch Data Throughout Tanzania Waters
3.3.1 Correlations Between Luciolates & Stolothriessa
3.3.2 Correlations Between Lates & Stolothriessa
3.4 Movements Assessed with Acoustic Apparatus
3.4.1 Simrad EK 120 Survey October 1973
3.4.2 Furuno Assessments of Biomass Shifts Feb 74
3.4.3 Ross Sounder Reconnaissance May 1975
3.4.4 EX 38 Reconnaissance July 75 & October 1975
3.5 Direct Measurement of Fish Movements
3.5.1 School Movements in Daylight
3.5.2 Night Layer Delineation
3.5.2.1 Attempts to Locate Layer Edges
3.5.2.2 Replicated Tracks

CHAPTER 4: DISCUSSIONS

REFERENCES LITERATURE CITED
MOVEMENTS OF PELAGIC FISH IN LAKE TANGANYIKA

CHAPTER 1: INTRODUCTION

Nightly catches by ring-netters fishing off Kigoma, Tanzania, in Lake Tanganyika, fluctuate on sequential dates. Both total catch and species composition differ markedly over a few days, and often from one night to the next. Either fishing techniques and efficiency or fish movements could explain catch fluctuations. In this paper we examine all available information of fish behavior in Lake Tanganyika to evaluate extent and rate of movement.

Lake Tanganyika covers 10,000 mi² and most of the lake bottom lies at least 500 m below the surface (maximum depth 1470 m). It is meromictic and oxygenated only in the upper 60 to 200 m, depending on area and season. The epilimnion deepens in the dry, windy season July-November. Thermal stratification is strongest in the wet, warm season December-April. The lake has visibilities of up to 22 m, although usual transparency lies around 10-16 m.

Six species make up practically all pelagic ichthyomass. They include two clupeid planktivores (Limnothrissa miodon and Stolothrissa tanganicae) and four predators (Lates angustifrons, L. mariae and L. microlepis, and Lucioliates stappersi). Stolothrissa makes up 10 to 75% of annual ring-net catches, and probably constitutes 60-70% of total pelagic ichthyomass.

Stolothrissa and Limnothrissa generally form schools in day time and settle into layers at night. The change from schools to layers occurs at 1900-1930 h and the return to schooling at 0600-0630 h. Layers may lie from 10 to 100 m deep. Lucioliates generally occupy the topmost 30 m in the water column, and Lates angustifrons and L. mariae usually remain below 50 m, often to 100-120 m. L. microlepis may tend to occupy shallower depths than the other two Lates species. The following points tend to support these observations: Eye size is largest in L. mariae, smaller in L. angustifrons, and smallest in L. microlepis and when the former two species surface in ring-net catches the air bladder often extrudes out of the mouth.
CHAPTER 2: METHODS

2.1 Indicators of fish movement

Sequential nightly catches by ring-netters fishing in the same location offer one indication of changes in fish distribution. We obtained such information from MV France, a ring-puter under charter to the Lake Tanganyika Fishery Research and Development Project. Over 9 months of charter we recorded catches by species and location. Where such catches occurred on sequential nights in the same location we used the data to indicate shifts in fish distribution.

Additionally, we obtained one series of catch data by MV France during one lunar month (October 1974) throughout the Tanzania waters of Lake Tanganyika. We combined this information with data from a simultaneous acoustic survey to evaluate major changes in fish distribution over time.

Acoustic surveys, repeated over a few hours or days, also serve to indicate whether fish distribution changes extensively. Several such surveys provided data for this paper.

We also directly measured rates of school movement with a crude "sonar", a modified Furuno echosounder.

2.2 Fishing methods

The 17-meter MV France, as all ring-netters on Lake Tanganyika (about 40 vessels as of June, 1976), fished a ring-net about 330 m long and 115 m deep, hand-pulled by a crew of 30. Normally 4 or 5 light-boats, each with 2000 candlepower lamps, attract fish for several hours, after which the fishing vessel sets the net around one or two light-boats. The system operates most effectively in the dark-of-the-moon period.

We tabulated fishing location on catch records to the nearest mile of distance and by 3 directions from Kigoma; northwest, west and southwest.

2.3 Extensive fishing in October 1974

In October 1974 we stratified Tanzania waters of the lake into 7 strata, then MV France fished in each stratum at randomly selected points, with 19 nights of the lunar month allocated on the basis of stratum area. Catches reflected lateral distribution of the several species.
2.4 Acoustic surveys

In October 1973 Johannesson (1974) completed a survey of Lake Tanganyika, using a Simrad EK 120 sounder, coupled with an echo integrator QM-MKII. The 12 m survey vessel recorded integrator data continuously, tracking at 6 k east-west across the lake at 6 mile intervals in the northern half and 10 mile intervals in the southern half of the lake (Fig. 1). The northernmost 700 n mi² (largely Burundi - Zaire waters) was surveyed twice, 14 days apart. Also, the vessel covered several long north-south tracks in the central and southern part of the lake which one can use for comparison with east-west tracks covered a few days earlier.

In February 1974 Chapman (1976) undertook repeated acoustic surveys off Kigoma with a Furuno echosounder which he had "calibrated" against Johannesson's Simrad system. Chapman regarded the Furunn data as good indices of relative fish abundance. He tracked at 6 k over rectangular grids of 48 to 100 n mi² at intervals of 24 hours to one week. Additionally we correlated Furuno echograms with commercial catches at given points. These data helped us to ascertain species indications on echograms.

In July, August and October 1975 we used a Simrad EK 38 sounder to determine fish distribution throughout Tanzanian waters of the Lake. Plankton hauls, explosives and lights helped evaluate targets on echograms so that we feel reasonably confident that large fish and Stolothrissa could be distinguished from plankton and from each other.

In May 1975, Mathisen (unpublished data) used a 105 kHz Rose sounder with calibration oscillator, interface unit (to convert 105 kHz to 5 kHz) and tape recorder to survey pelagic ichthyomass on a single north to south track down the lake center.
2.5 School tracking

Early in 1976 we modified a Furuno Mark III sounder to increase paper
speed from 100 to 200 cm/20 min and to 0-120m vertical scale. Next we
mounted the transducer at a 45 degree angle from horizontal and placed it on
a 3 m pipe attached to the gunwhale in a manner which permitted an operator to
observe the echogram while he slowly rotated the transducer fore and aft.

When the operator located a school of fish within 120 m of the trans-
ducer face, he rotated the transducer past the school at least twice to
assess the strongest trace. Times and distances were then recorded repeatedly
until the school was lost or left the 120 m range.

In Figure 2 we illustrate some example trigonometry of school movement
as assessed with the described system, assuming no vessel movement. The
transducer had 28 degrees beam width and 14 degrees fore-aft beam width,
mounted so that the wide beam width recorded vertically on the echogram
(long axis of the transducer fore and aft with vessel length).

In Figure 3 we illustrate two slightly more-complex cases in which
the vessel drifted with the wind, together with a plot of school movements
assessed after correction for vessel movement.

Procedures called for commencing all school tracking at an anchored
buoy (depth 860 m) 4.5 miles northwest of Kigoma. At that point we set
drogues at 5, 10, 25, 50 and 75 m, each connected to a separate small
float. In addition we released a radar reflector-float on a 5 m drogue at the
same point. Radar fixes on the anchored buoy served to roughly assess
distances moved by drogues in a given time. Radar fixes on the anchored
buoy proved useful for assessment of direction and speed of vessel drift.

A Simrad EK 30 sounder served to accurately measure depth of tracked
schools when the latter happened to pass beneath the vertically-mounted
Simrad transducer. These measurements compared quite favorably with Furuno-
estimated depths at which we tracked schools.
2.6 Layer declination

We attempted to assess movements of layers of Stolothrissa at night by repeatedly tracking over the same areas on radar-controlled paths, recording fish echoes on an EK 38 sounder. At first we tried to delineate edges of layers at several points, but soon switched to a repeated north-south track of 12 miles from Bangwe Point to southward. Usually we completed 6 to 8 repetitions between 2000 and 0600 h.

We subjectively assessed densities of various layers as 1 (least dense echo trace), 2 (moderate density) and 3 (highest density).
CHAPTER 3: RESULTS

3.1 Sequential ring-net catches

On 20 sequentially-paired nights in which MV France fished at the same location, catches of Stolothrissa and Luciolates did not correlate significantly (Figure 4 and 5). Sequential catches of Lates spp. correlated significantly (P=0.10) (Figure 6). From Figure 4 we can note that catches of Stolothrissa drastically varied from night to night in the same location. In 4 pairs catches on successive nights changed from zero to about 1000 kg. Catches of Luciolates varied less-sharply, and on only one pair of nights did the catch change as greatly as from 0 to 1000 kg. Catches of Lates remained much more stable (Figure 6). We infer from these data that Stolothrissa probably move more rapidly than the other pelagic species, and probably aggregate more strongly. Luciolates, and especially Lates, either move about less rapidly or generally distribute themselves less patchily than do Stolothrissa so that if they move from a given spot another group of fish may move in to the vacated area quickly.

3.2 Composition of ring-net catches

3.2.1 Correlations between Luciolates and Stolothrissa

Catches of Luciolates and Stolothrissa correlate inversely in Burundi (Ellis, 1975) and in the Kigoma area (Figures 87 & 98). We calculated a regression of Luciolates catch per ring-net set against catch per set of Stolothrissa for 74 nights in the period July-December when the latter were abundant and mean Stolothrissa catch equalled 153 kg/set, finding an inverse correlation significant at P = 0.001. In this period mean Luciolates catch equalled 59 kg/set. Similar calculations for the period of lowest Stolothrissa abundance, January-May (70 nights, mean catch 22 kg/set), also revealed an inverse correlation at P = .001. In this period mean Luciolates catch equalled 194 kg/set.
Curvilinear regressions of the form $Y = a + bX + cX^2$ reduced residual error and increased significance level for the test of slope $= 0$. Hence we plotted the resulting curves in Figures 7 and 8. Curves for the periods of low and high Stolothriassa abundance appear very similar. The correlations are highly significant in all cases, in spite of widely variable total catches. We may interpret them as follows:


2. Given the known predatory character of Luciolates (Ellis, 1975) Stolothriassa probably has adapted to interaction with the predator by adopting dense schooling and rapid lateral movements around the lake, thus facilitating depensatory mortality in the face of predators with limited short-term consumption. Individual clupeids in dense schools have greater survival probability.

3.2.2 Correlations between Latas and Stolothriassa

In arithmetic correlations between abundance of Stolothriassa and Latas we noted a significant positive correlation at $P = 0.10$. That is, Latas tended to be more abundant when Stolothriassa density increased. Plots of the data showed that Latas mariae and L. angustifrons did not contribute to the positive correlation. Therefore we logged and correlated the catch/set positively with Stolothriassa catch ($P = 0.001$) in spite of wide variations in catches of both species (Figure 9).

It appears that L. microlepis may follow Stolothriassa fairly effectively. Body conformation of this predator conforms to that of a streamlined predator capable of sustained rapid movements. They often feed vigorously at the surface on Stolothriassa.
Finally, we correlated catch/set of *Lates microlepis* with catch of *Stolothrissa* one night earlier in the same location. For 33 such pairs we found no significant correlation. We conclude that *L. Microlepis* more effectively follow *Stolothrissa* than do the other major predators.

3.3 Catch data throughout Tanzanian waters

3.3.1 Correlations between *Luciolates* and *Stolothrissa*

In Figure 10 we show catches per set by species in the test fishing of October 1974. Linear regression of logged *Luciolates* catch/set against *Stolothrissa* catch/set for 19 nights of fishing throughout Tanzanian waters (Figure 11) of the lake yielded a significant negative correlation (*P* = 0.001 and *F* = 17.0). Curvilinear regression improved the negative correlation very slightly (*P* = 0.001 and *F* = 23). These results conform closely to those obtained off Kigoma (Section 3.2.1).

3.3.2 Correlations between *Lates* and *Stolothrissa*

Plots of catch/set for *Lates microlepis* and *L. mariae* against *Stolothrissa* obviously did not indicate positive correlations for *L. microlepis*, but did for *L. mariae*. Linear regression revealed in the latter case that *L. mariae* catch/set correlated positively and significantly (*P* = 0.05) with *Stolothrissa* catch/set. We cannot explain why the catch of *L. microlepis* correlated positively with catch of *Stolothrissa* in 74 nights off Kigoma (Section 3.2.2) but not in 19 nights throughout Tanzanian waters, or why the catch of *L. mariae* correlated positively with *Stolothrissa* in the October 1974 survey. Chances are about 1 in 20 that the latter occurred by chance alone, but less than 1 in 1000 that the correlation off Kigoma was due to chance alone.

One difficulty in correlating catches over a period as short as 20 days throughout a wide geographical area is that one never knows whether the prey or predator species departed or arrived shortly before fishing commenced. Therefore we tend to place more reliance on data obtained off Kigoma in 74 nights.
3.4 Movements assessed with acoustical apparatus

3.4.1 Simrad EK 120 survey October 1973

Two surveys were completed in the northern tip of the lake (Figure 1) 14 days apart. Mean ichthyomass per two-mile track (Johannesson 1974) at night in the second survey significantly exceeded that in the first survey ($P < 0.001$). Plotted integrator data in Figure 12 indicate shifts in centers of abundance over the two weeks as well as a substantial influx of fish from Tanzania/Zaire.

Comparison of integrator data from long north-south tracks throughout the lake with those from primary east-west tracks in the same locations revealed large differences in fish density over 3 days.

3.4.2 Furuno assessments of biomass shifts February 1974

In repeated surveys over a rectangular area of 48-100 n mi$^2$ off Kigoma Chapman (1974) noted very obvious horizontal movements of fish over periods of a week and over 24 hours (Figure 13).

3.4.3 Ross sounder reconnaissance May 1975

Mathisen (unpublished report to FAO Lake Tanganyika Project, Kigoma) reported higher ichthyomasses in the southernmost 40% of the lake than in the remainder. In October 1973 the Simrad survey reported no significant difference between biomasses in the north and south halves of the lake (Chapman 1975).

3.4.5 EK 38 reconnaissance July 1975 and October 1975

In July 1975 we found Stolothrissa targets in both north and south halves of the Tanzania part of the lake, with highest densities northwest of Kigoma and south of Kibwesa to Kala. In October Stolothrissa did not appear south of Karembo but were abundant Karembo - Kibwesa and Mgambo - Kabogo south of Kigoma.
3.5 Direct Measurement of Fish Movements

3.5.1 School Movements in Daylight

For 78 schools "sonar"-tracked in the period 26/1 to 22/4/76 we plotted rates and directions of movements (Figure 14). Movements of schools presumed to be Stolothrissa ranged from near zero to 68 m/min. In 71 cases in which schools moved discernibly, 29% of the schools moved northward (315° - 45°), 44% moved eastward (45° - 135°) towards the shore (in 3.5 miles), 18% moved southwards (135° - 225°) and 9% moved westwards (225° - 315°).

For 69% of the schools current is the observed depth range 0-25 m was southwards (180°), for 18% northwards (345°) and for 13% north-westwards (295°).

Mean net movement 7 of 22 schools (10 observations) equalled 11.4 m/min, standard deviation 9.7 (taking the direct connection start point-end point as distance). The mean total movement equalled 20.1 m/min, standard deviation 10.7.

3.5.2 Night Layer delineation

3.5.2.1 Attempts to Locate Layer Edges.

On 26/11/75 we located a large layer of fish about 40 m below the surface 3 miles off Kigoma. The layer was large enough so that we could locate only the NE and W edges. Repeated tracks across these edges indicated that the layer did not move during the night. On 28/11/75 the N edge of this layer had moved 9 miles south-southwest. Current at the time measured 0.27 km/h to the south.

On 20/1/76 3 small layers were detected about 2030 h, disappearing about 2200 h into a large layer which covered several square miles and lay about 50-75 m deep. By 2300 h the south edge of this layer moved north-west at a rate apparently equalling about 2.2 km/h. The eastern edge moved west at about 1 km/h between 2100 and 0400 h.

On 26/1/76 we located three laterally discrete layers of fish between 2100 and 2400 h. During 7 hours of tracking the borders of these groups did not change position.
3.5.2.2. Replicated tracks

On 2/2/76 (Figure 15) we tracked 4 times over the same 17 km NS course about 4 km off Bongwe Point. The layer apparently moved southward slightly over 7 hours, although we could not definitely establish a rate, as the layer edge was unclear.

On 9/2/76 we replicated tracks near Bongwe Point, locating 2 schools at 25 m and one large layer at 50-75 m (Figure 16). One school disappeared on the second track, the other moved south at about 0.6 km/h. (with the current) and finally joined the deeper, denser layer at 0500 h (Figure 16).

On 16/2/76 we replicated 17 km tracks off Bongwe Point (Figure 16), concluding that a layer at about 50 m moved southward at 0.5 km/h (again with the current). At midnight in a bright, full moon, daytime school shapes appeared at the surface above the layer.

On 23/2/76 replicated tracks indicated that two layers (Figure 17) at 50-75 m did not move north-south measurably over the night.

Replicated tracks on 8/3/76 (Figure 17) indicated no north-south movement of a layer at 50 m, although a smaller layer at 25 m did move deeper over several hours.

On 15/3/76 (Figure 18) a layer of fish at 25-35 m disappeared as the full moon brightened, the layer apparently diffusing and some fish forming daytime schools near the surface.

On 22/3/76 and 5/4/76 (Figure 18) fairly dense layers were repeatedly traversed north-south. They did not change position materially overnight.

We conclude from the attempts to delineate layers that night movement was usually negligible, although movements at 0.4 - 0.6 km/hr apparently with the prevailing current, occurred on 3 of 8 nights.
CHAPTER 4: DISCUSSION

Chapman (1975) and Bazigos (1975) demonstrated that pelagic ichthyomass aggregates strongly in a contagious distribution. Inasmuch as the bulk of the fish biomass consists of *Stolothrissa*, we deduce that *Stolothrissa* aggregates strongly.

From all available information we conclude that *Stolothrissa* move long distances fairly rapidly. Significant movements take place over periods as short as 24 hours. School and night layer tracking indicate that most of this movement takes place in daytime, when schools move at rates as high as 68 m/min (10 m/min median rate for 63 schools tracked).

Abundance of *Luciolates* correlates inversely with that of *Stolothrissa*. We suggest that *Stolothrissa* moderately effectively avoids concentrations of *Luciolates*. Abundance of *Lates microlepis* tends to correlate positively with that of *Stolothrissa*, a fact which suggests that the prey species does not avoid this predator as well as it avoids *Luciolates*.

Movements of *Stolothrissa* may involve another aspect of population ecology: that of plankton abundance. Rufli and Chapman (1975) demonstrated that abundance of plankton and pelagic ichthyomass (again largely *Stolothrissa* by inference) correlated inversely. Some of the apparently rapid movements of *Stolothrissa* may involve food-seeking. We see a high likelihood that a model which explains clupeid movement would contain elements of both predator avoidance and food search.

Clupeids may tend to move contra-current. Currents off Kigoma are almost exclusively southward. School tracking suggests that more schools moved northward than southward, and Chapman and Van Well (1975) reported that the experienced skipper of MV France tended to relocate dense fish concentrations, by moving northward. Further, they reported that in searching for new concentrations, the skipper succeeded more often by moving south, the direction from which new concentrations should come if clupeids move contra-current.

From a fishery development point of view, we state that the fishery and markets of Kigoma and other landing points as well, must expect very large fluctuations in nightly catch. Efficient fish-hunting equipment (eg sonar) should stabilize catches somewhat, but cannot remove fluctuations entirely because clupeids aggregate strongly, forming patchy distributions, and because fleet daily range is limited to about 12-15 miles.
LITERATURE CITED


Fig. 2 School-tracking trigonometry example.

\[ \begin{align*}
\theta_0 &= \text{time when school is first detected} \\
F_1 &= \frac{D}{\sin 59^\circ} = 1.17D \\
M_1 &= \frac{D}{\tan 59^\circ} = 0.60D \\
\end{align*} \]

\[ \begin{align*}
t_{\text{end}} &= \text{time when school leaves Furuno range} \\
F_3 &= \frac{D}{\sin 31^\circ} = 1.94D \\
M_3 &= \frac{D}{\tan 31^\circ} = 1.66D \\
t_i &= \text{any time during } t_0 \rightarrow t_{\text{end}} \\
F_2 &= \frac{D}{\sin \alpha_i} \\
M_2 &= \sqrt{F_2^2 - D^2} \\
\end{align*} \]

Note: Where school depth is shallow
Fig. 3. Example of drift correction for school tracking. Refer to Fig. 3 also.
Fig. 48 Correlation of catch/sea of Stolothrissa and Luciolates,
January - May 1975.
Fig. 10: Correlation of catch/set *Stelatoma* with catch/set *Luciolumena* micro-les, same day, July - December 1974.

Fig. 11: Correlation of catch/set *Stelatoma* with catch/set *Luciolumena* October 1974, throughout *H. gibba* waters.
Fig. 5. Sonar track school movements all related to 0-25 m current drogue data obtained on 11 days, 26/1-22/4/76
4.5 m/sec NW of Vigo area.

- O = 3-10 observations
- x = >10 observations

68 m/min

10 m/min
Fig. 17. Regulated forms near Fig. 17. Regulated forms near

- 23/Feb/76

1 2 3 4 5 6 7 8
0127 0127 0127 0127 0127 0127 0127 0127
0242 0242 0242 0242 0242 0242 0242 0242
0404 0404 0404 0404 0404 0404 0404 0404
0540 0540 0540 0540 0540 0540 0540 0540

1 2 3 4 5 6 7 8
0022 0022 0022 0022 0022 0022 0022 0022
0240 0240 0240 0240 0240 0240 0240 0240
0540 0540 0540 0540 0540 0540 0540 0540

- 8/Mar/76

1 2 3 4 5 6 7 8
1954 2245 2245 0123 0123 0412 0412 0412
0123 0123 0123 0123 0123 0123 0123 0123
0432 0432 0432 0432 0432 0432 0432 0432

1 2 3 4 5 6 7 8
2142 2142 2142 2142 2142 2142 2142 2142
0000 0000 0000 0000 0000 0000 0000 0000
0240 0240 0240 0240 0240 0240 0240 0240
0540 0540 0540 0540 0540 0540 0540 0540

N

- 0-125 m