A PORTABLE CEILOMETER TECHNIQUE FOR STUDYING LOW-LEVEL NOCTURNAL MIGRATION

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INTRODUCTION

During the course of simultaneous telescopic and radar studies of bird migration on the northern coast of the Gulf of Mexico, the need arose to study visually the overhead passage of nocturnal migration when no moon was visible. The moon-watching technique (Lowery, 1951) is limited to full-moon periods when there is no obscuring cloud cover. Howell *et al.* (1954) and Graber and Hassler (1962) demonstrated that migrating birds could be observed with powerful light beams. In 1965 and 1966 I made observations of nocturnal migration at fixed-beam ceilometers operated by the United States Weather Bureau at Lake Charles and at New Orleans, Louisiana. These observations showed that very few birds were affected by the light; most flew through the beam without hesitation or deviation in direction. No kills of migrants were recorded at either of these ceilometers during the two year period. Since fixed-beam ceilometers at airport weather stations are rapidly being replaced by rotating-beam devices that are unsuitable for migration studies, I have constructed and tested a small, portable ceilometer apparatus for visual studies of nocturnal migration. The apparatus is inexpensive and easily built.

EQUIPMENT AND METHODS

The portable ceilometer (Figure 1) consists of an eight-inch General Electric PAR 64, 6-volt, 100 watt ceilometer lamp connected to a Thordarson or Stancor filament transformer. The transformer has a primary of 117/107 volts (50/60 cycles per second) and a secondary of 6.3 volts (10 amp). It is mounted either on the floor or the side of a box with dimensions slightly smaller then the diameter of the lamp. The bulb is connected to the secondary of the transformer and rests on the four sides of the open box; the primary is connected to an extension cord which passes through a hole in one side of the box and goes to a household power source. All of these components of the apparatus may be purchased for about fourteen dollars. The bulb will last the length of a migration season with moderate use. If one connects the ceilometer bulb(s) to either a 6-volt or a 12-volt car battery, the transformer is not needed; a single lamp can operate from a 6-volt battery, and two lamps wired in series can operate from a 12-volt battery. This modification eliminates the need of being in an area with electrical outlets.

The methods employed for telescopic observations are essentially those described by Lowery and Newman (1963) for daytime observation of the sky. A telescope is mounted vertically with the space sampled aligned in the vertical lighted cone. The position of the telescope relative to that of the ceilometer determines the

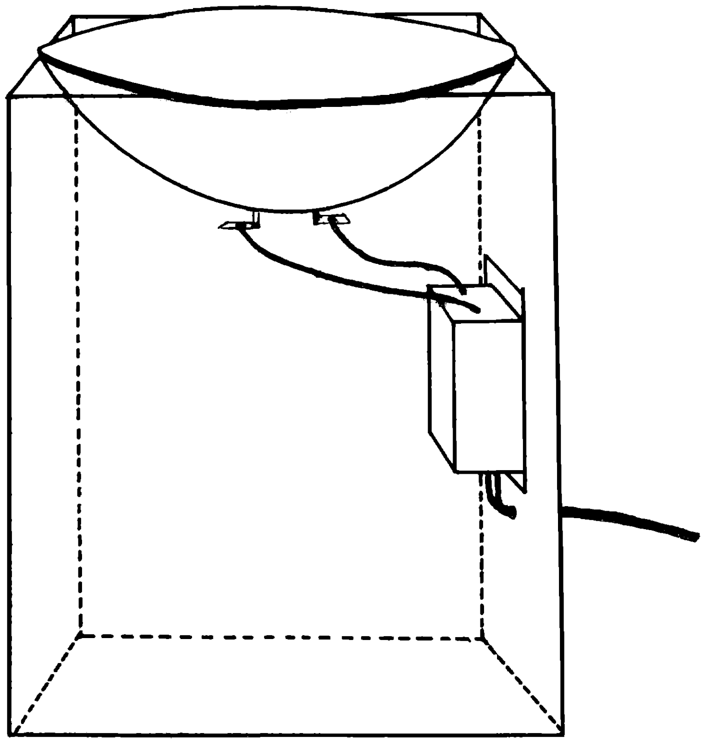

Figure 1. Diagram of the portable ceilometer system.

altitude at which the telescopic cone will penetrate the light beam. The spread of the ceilometer beam is about 7°; the field width of the 20 x 60 telescope is 2.5°. When the telescope is positioned within five feet of the ceilometer, a low-level interference zone of brilliantly illuminated insects and dust particles makes observation difficult. This difficulty can be overcome by moving the telescope 5 to 10 ft away from the ceilometer. Even under the best conditions insects and bats may confuse an observer, but these contaminants are usually identifiable by their manner of flight.

As birds cross the field of the telescope their directions can be recorded in polar coordinates (e.g., N, SW, E), but I suggest that an observer use the clockface method of determining flight directions (Lowery and Newman, 1963). First, the observer must be supine with his body axis aligned north-south so that his head is directed north (the North Star provides a convenient reference point on clear nights). Secondly, the observer must imagine that the circular patch of sky seen through the scope is a numbered clockface with 6 o'clock at the point nearest the observer's feet. The flight paths of birds are recorded in terms of clock points, e.g., in at 6 o'clock and

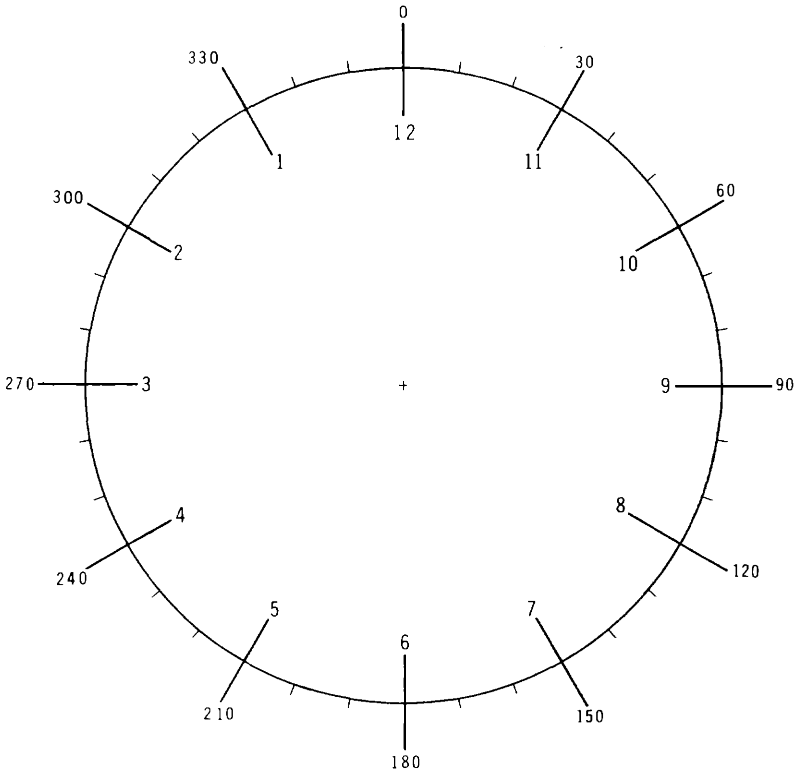

Figure 2. Diagrammatic plot for determining the paths of flight. All paths in terms of clock-coordinates must pass through center before being read on the azimuth ring.

out at 2 o'clock. Directions can usually be expressed with half-hour accuracy.

The flight directions of birds expressed in clock coordinates can easily be converted to azimuth directions with the aid of Figure 2. All clock directions that pass through the center of Figure 2 can be converted to azimuth directions directly. All clock directions that do not pass through center must be handled differently. With a transparent overlay sheet of parallel lines every 2-3 mm one can readily shift off-center clock directions to their equivalents through center and then read the azimuth direction. Since an observer is looking up at the clockface when viewing birds through the telescope, 9 o'clock represents 90° or east, and 3 o'clock represents 270° or west. In order to maintain this relationship and have the azimuth ring oriented in a conventional manner, the clock points have been reversed on Figure 2.

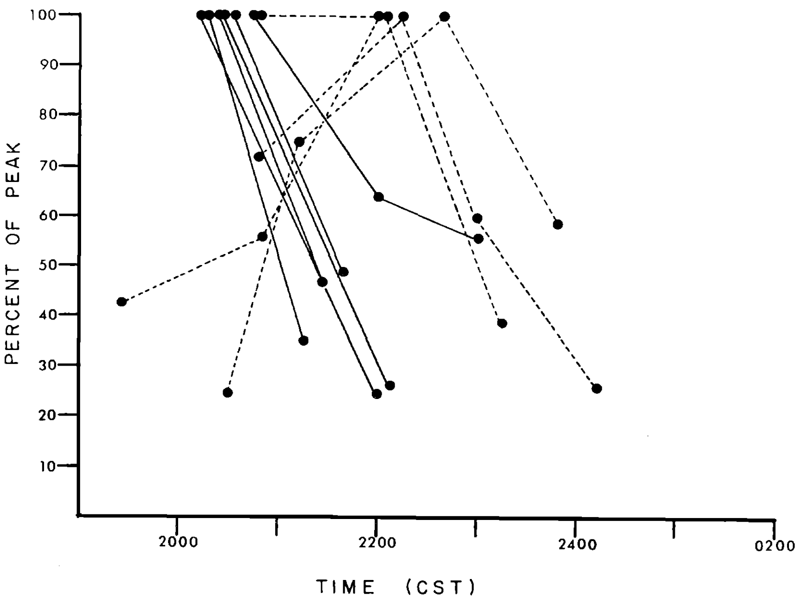

Figure 3. Hour-to-hour variation in the amount of nocturnal migration in southeastern Louisiana during the spring of 1967. The solid lines show the normal decline in the amount of migration before midnight. The broken lines show occasions when the migration lasted until later in the night due to the late arrival of trans-Gulf flights.

RESULTS

Two tests were conducted to determine the distance at which an observer can see a bird illuminated by the ceilometer. On a cool, moonless night two ceilometer lamps were wired in series with a 12-volt car battery, and the lights were directed down a country road that was straight, paved, and unlighted. Both 7 x 50 binoculars and a 20-power telescope were used to view study skins suspended one at a time from the end of a black pole at certain distances down the road. The species used included: Catbird (*Dumetella carolinensis*), Wood Thrush (*Hylocichla mustelina*), Red-eyed Vireo (*Vireo olivaceus*), Parula Warbler (*Parula americana*), and Summer Tanager (*Piranga rubra*). When illuminated by two lights all birds were visible through 7-power binoculars at 1,000 ft. With a 20-power telescope, all birds were visible when illuminated by one bulb at 1,000 ft, and most were seen with only one bulb at 1,500 ft. The Wood Thrush when illuminated by one bulb was clearly visible through the telescope at a distance of 2,100 ft.

In another test on a clear, moonless night, a 20-power telescope was used to view migrants flying through the beam of a portable ceilometer positioned near the 1,750-ft WAFB-TV tower in Baton

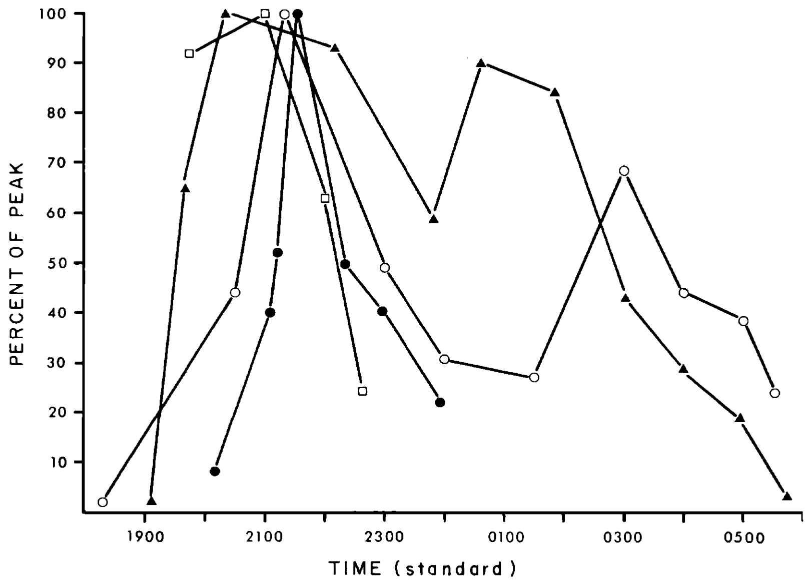

Figure 4. Hour-to-hour variation in the amount of nocturnal migration during the fall. Open circle—night of 26-27 September 1968, Athens, Ga. Solid triangle—night of 4-5 October 1968, Athens, Ga. Open square—night of 1-2 October 1968, Athens, Ga. Solid circle—night of 23-24 September 1967, Baton Rouge, La.

Rouge. Since the guy lines connect with the tower at 190-ft intervals, I was able to record the altitudes of the birds as they flew near the tower. All passerines flying below 1,500 ft appeared distinct, and some passerines above this altitude were clearly visible.

Most of the birds flying through the ceilometer beam have been passerines. Only rarely have I seen waterfowl and shore birds. Even though migrants dart through the beam and are visible for only a very short time, I have identified some birds specifically on the basis of their shape and color characteristics.

The changing quantity of nocturnal migration.—Figures 3 and 4 illustrate some temporal patterns of migration based on ceilometer data collected in spring and fall, respectively. The spring data were gathered in New Orleans during 1967; the fall data were obtained at Baton Rouge in 1967, and at Athens, Georgia in 1968.

The data I obtained during the spring of 1967 show that the number of migrants aloft increased sharply after the end of civil twilight, peaked about 20:00 to 21:00 hours, or about an hour to two hours after dark, and decreased until 22:00 to 23:00 hours when the emigration from coastal Louisiana ended. When trans-

TABLE 1. FLIGHT DIRECTIONS OF MIGRANTS IN SPRING

Date	Time	Number of Migrants per 20° Sector																	
		9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28	29-30	31-32	33-34	35-36	1-2	3-4	5-6	7-8
9 Apr. 67	2030-2100 C												2	3	4		2	2	
	2145-2215 C											3	2	1	4		2		
	2300-2330 C												2		2		2		
28 Apr. 67	2020-2050 C										1	8	19	4	10	8	1	2	
	2152-2222 C									1	1	1	3		3	2		2	
29 Apr. 67	2001-2030 C										1	1	4	3	8	2	1		
	2100-2130 C										1		4	2					
5 May 67	2012-2047 C									1		1	2	5					
	2110-2136 C															1		3	
10 May 67	2020-2050 C											1	2	6		2		4	
	2130-2200 C											1	1	2	1			3	
12 May 67	1958-2030 C											1	2	2	7	1	3	6	2
	2150-2210 C												2		1	1			

TABLE 2. FLIGHT DIRECTIONS OF MIGRANTS IN AUTUMN

Date	Time		Number of Migrants per 20° Sector																	
			9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28	29-30	31-32	33-34	35-36	1-2	3-4	5-6	7-8
16 Sept. 67	2025-2045	C		3	3	7	9	5												
	2054-2124	C			1	3	11	7	5	12	5									
	2131-2212	C		2	1	1	8	5	5	7	3	9	2							
17 Sept. 67	1846-1905	C						2		1		1							1	
	1943-2009	C			1			2	1			4	1			1			1	
19 Sept. 67	2019-2041	C			1						2	2		2	2	2	1			
	2122-2142	C				1	3		1	8	1	4				4				
23 Sept. 67	1915-2125	C	1	1		4	47	25	27	23	7	5	1			2	1			
	2206-2255	C		1	1	2	5	15	49	69	16	8	1					1		
28 Sept. 67	2110-2120	C		1	1	1	8	4	3	3	2									
	2150-2200	C			3		7	1	2		1									
	2225-2240	C		4	1	2	4		3	1										
	2252-2302	C					3		1	3	1									
	2307-2312	C				1	1		1		1				1					
26 Sept. 68	2010-2030	E	1	1	1	1	5	13	7	8		1			1					1
	2105-2130	E	2	7	4	1	12	16	9	11	8							1		
	2250-2313	E		1	1	1	10	3	13	12	4	1								
	2350-0022	E		1	3	2	8	3	4	15	7									
	0120-0145	E		3	1	1	6	5	3	8	6									
	0245-0305	E				1	3	6	17	20	7					1				
	0340-0405	E					2	5	13	18	5			1						
	0435-0455	E					1		5	15	8									
	0520-0535	E							1	7	11	1								

TABLE 2. (continued)

Date	Time	9-11	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26	27-28	29-30	31-32	33-34	35-36	1-2	3-4	5-6	7-8
		Number of Migrants per 20° Sector																	
1 Oct. 68	1930-1955 E		2		1		2	1	4	11	10	1	1						
	2030-2133 E					1	2	1	5	10	23	6	2		1			2	
	2145-2207 E				1		1	1		1	3	10	2						1
	2230-2247 E											1	5						
4 Oct 68	1930-1946 E		1	7	4	18	7	3	1										
	2010-2030 E		1	1	4	27	25	10	7										
	2155-2217 E				1	9	15	24	21	5									
	2320-2343 E					2	2	4	33	13									
	0025-0045 E						1	12	37		3								
	0140-0200 E						2	6	34	11	3								
	0253-0316 E								20	13	1								
	0400-0414 E						1	1	6	7		1							
	0447-0508 E								7	6	1	1							
	0530-0555 E									1	2								

Gulf migrations continued to arrive on the northern coast of the Gulf of Mexico after dark, the duration was lengthened and peak movement occurred later. The end of a night's migration on such occasions was retarded until 24:00 to 01:00 hours (Figure 3, dashed lines).

Some examples of temporal patterns obtained with the ceilometer during fall migration are shown in Figure 4. In fall, peak migration occurred from 20:30 to 21:30 hours. Occasionally a subsequent peak appeared after midnight, and by dawn the migration was greatly reduced in magnitude.

The direction of migration.—Tables 1 and 2 give information on the directional tendencies of migrants as they flew through the light beam in spring and fall, respectively. In spring the orientation of the flights was northerly, with northwest, north, and northeast components (Table 1). Most of the low birds flew northwesterly while higher migrants moved northerly and northeasterly. These flight directions paralleled the prevailing wind directions aloft in southern Louisiana during April and May of 1967 (United States Weather Bureau, Climatological Data, 1967).

The orientation of fall flights was principally to the southwest (Table 2). Early in the night some migrants moved southeasterly, but this component decreased later in the night. In addition, the direction of migration appeared to shift more westerly as the night progressed. The shift was most noticeable when observations spanned the entire night (e.g., 26 September and 4 October 1968). The data from 16 and 23 September 1967 were collected 50 ft away from the base of the 1,750-ft WAFB-TV tower in Baton Rouge. The direction of migration was not affected by the tower (Table 2); on both nights the sky was clear and the wind below 2,000 ft was from the north and northeast. The direction of migration on 19 September 1967 was to the northwest during the hour 20:00-21:00 but shifted to the southwest an hour later. On 1 October 1968 the bulk of the migration was directed to the west, and on this night the cloud cover was less than five tenths and the wind between ground level and 3,000 ft was blowing toward the west.

Migration and overcast.—I have collected only limited ceilometer data on overcast nights, but it appears that the quantity of migration taking place below solid cloud cover is reduced when the cloud deck is less than 2,000 ft. At New Orleans on 4 May 1967 at 21:00 hours cloud cover was 100 % at 1,400 ft, and on 5 May 1967 at the same time cloud cover was 90% at 600 ft. Although I heard numerous call notes and simultaneous radar information confirmed that heavy migrations were underway on both nights, the number of migrants recorded with the ceilometer was far below the expected number. On 4 May only two birds were seen below the overcast during an hour of observation. On 5 May I observed migrants passing through the beam only when clear openings or holes in the cloud deck were overhead (Table 1). When solid overcast was above 2,000 ft, the number of migrants recorded was comparable to that on clear nights (28 April 1967—Table 1).

DISCUSSION

Because the telescope is mounted vertically and the cone of observation remains unchanged, data accumulated by the ceilometer technique are standardized. Raw counts of birds converted to numbers passing per hour enable one to compare low-level migration and its direction of movement at different times of the evening, from evening to evening, from fall to spring, and from place to place. Moreover, one can identify the general kinds of birds that are migrating.

Atmospheric haze and very low cloud cover can seriously limit observation. The altitude of the migration can also influence the number of migrants seen with the ceilometer. When most migration is above 2,000 ft the ceilometer technique will not yield meaningful results. The magnification of the optical instrument used with the portable ceilometer can also limit the altitude at which migrants are seen. An observer using 7-power binoculars will often fail to record high-flying birds that are visible with a 20-power scope. Additional ceilometer bulbs will increase the illumination of high-flying birds, but the additions lessen the portability of the unit and increase the cost. If available, airport ceiling lights and fixed-beam ceilometers can be used to study nocturnal migration.

Radar studies of migration are not possible in many geographical areas, and where radar coverage exists, sampling of low-level migration is often impossible. A number of investigators (Lack, 1960; Mascher *et al.*, 1962; Gehring, 1963; Wilcock, 1964; Eastwood, 1967; Graber, 1968) discovered that radar gives inadequate or no information on migration below 2,000 ft. Since the ceilometer technique is best suited for studies of low-level migration, it can be used to complement radar studies of nocturnal migration. The technique is also useful for determining the extent of low-level migration under solid cloud cover.

The temporal distribution of nocturnal migration in spring that I computed from ceilometer data agrees with the patterns that Lowery (1951: 422) derived from moon-watching and Steinke (1968) obtained from ceilometer data in southeastern Louisiana. The limited land area south of the observation stations and the brief departure time of migrants contribute to the short duration of a night's migration in southeastern Louisiana (Gauthreaux, 1968). Autumnal nocturnal migration is longer in duration probably because the geographical source areas to the north are extensive.

Graber (1968), on the basis of radar and call note data, suggested that migrants do not alight at night, that the migrant swarm is compressed into an altitudinal stratum below 1,500 ft, and that the increased rate of calling by the migrants functions in spacing the birds as an anti-collision system. Since Graber's radar misses that portion of migration below 1,500 ft, I have used the ceilometer technique to test his hypothesis. Migrants must certainly land at night for although the number of birds passing through the ceilometer beam occasionally increased after midnight, the amount of migration decreased *before* dawn. On those nights when the migration lasted until daybreak, the amount of migration aloft the hour before dawn was only 30-40 per cent of the amount of migration recorded at the peak hour earlier in the night. Cochran *et al.* (1967) found that migrating thrushes with attached telemetry devices did land at night, but they did not select their typical daytime habitat. Since the hour-to-hour variation in the number of call notes heard overhead is inversely proportional to the temporal variation in the number of migrants aloft (Graber, 1968), calling may have an important communication function in the landing behavior of nocturnal migrants.

The change in the direction of fall migration through the beam during the night was noticeable even when the migrants were passing close to a television tower (e.g., 16 and 23 September 1967). In autumn the shift was in the direction of star movement. In spring the duration of the flights from southern Louisiana was so short it was impossible to acquire meaningful data. Other workers have reported similar shifts in the direction of migration. Gehring (1963) observed a change in the direction of diurnal migration in Switzerland and suggested that if the birds used an uncorrected sun-or star-compass mechanism of orientation, they would be expected to show a shift in orientation. Drury and Nisbet (1964) found that the tracks of fall migrants on radar shifted about 1.5° per hour to the west during the night, and Nisbet and Drury (1967) recorded mean tracks of spring migrants that turned toward the right about 7° during the hours between 20:00 and midnight and returned to the left during the subsequent four hours. The latter authors attribute the change in direction to populations of migrants coming from different source areas. Graber (1968) also reported a significant westward shift in the direction of migration during the night in fall.

After testing the capabilities of the ceilometer technique, I question the statements of Graber and Hassler (1962) concerning the altitude at which they observed passerine birds in their light system. They claimed to have seen a passerine at 9,000 ft while observing with 7 x 50 binoculars. Even a large passerine would be virtually unidentifiable if observed with 7-power binoculars at a distance of 9,000 ft. Graber and Hassler were probably seeing birds below 1,500 ft, but due to the recovery time of their APS radar, these birds were not displayed on the radar screen.

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SUMMARY

A simple, inexpensive ceilometer technique is described for obtaining data on the nocturnal migration of birds. An observer can

identify, quantify, and determine the direction of nocturnal migrants as they fly through the field of a telescope directed up the light beam. Some preliminary results are presented and are discussed. The technique satisfies the need for direct visual methods of studying migration on moonless nights.

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