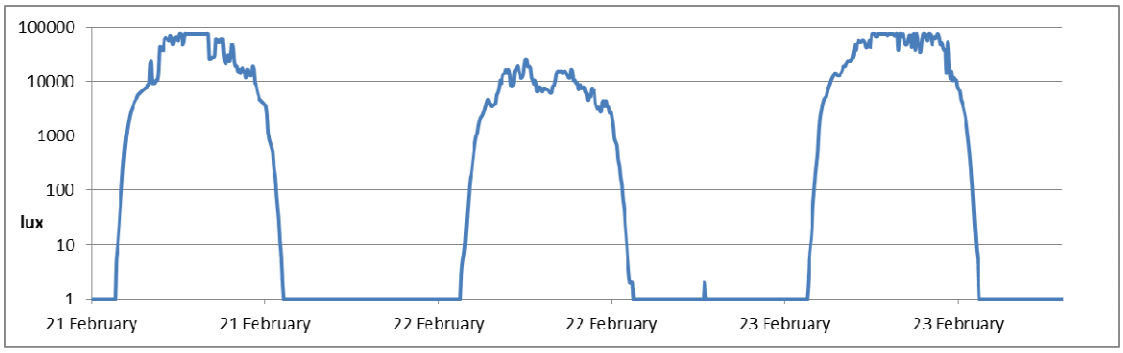
Intigeo® series geolocator

James W. Fox, Dec 2017

Migrate Technology Ltd presents the Intigeo series of light level geolocators. The Intigeo is a miniature archival electronic logging engine capable of recording near full range ambient light with complementing temperature and conductivity indicators allowing location tracking and behavioural studies of far ranging animals.

Intigeo loggers must be retrieved to obtain recorded data. Using the threshold level geolocation method, primary tracking data can be derived from the identification of sunrise and sunset events in the light record enabling latitude and longitude calculation twice daily e.g. using the R package GeoLight with or without our own IntiProc front end. The light range capability of Intigeos also allows curve/template statistical modelling analysis e.g. using the R packages FLightR, SGAT or tripEstimation.

- Light, temperature, wet/dry and conductivity sensing
- Curve/template or traditional threshold analysis possible
- Start time and device serial number recorded internally
- Intigeo can be started and stopped as many times as battery life allows. Data memory is reset when logging is started.



An example of 3 days light data from an Intigeo. Varying cloud thickness can be seen (day 2 is overcast). Threshold level geolocation would normally use less than 10lux but higher values allow behavioural study and cloud compensation, as well as advanced curve analysis and 24hr polar light location fixing.

1. Ambient light level recording

For geolocation light is sampled every minute but only the maximum sample value within each interval (5/10min) is recorded.

- 1-74,000lux (clipped for some logging modes)
- Resolution: quasi-logarithmic, 249 discrete levels
- Temperature compensated light sensor

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What this means: Due to the 1min sampling and maximum sample value recording regime, time resolution for geolocation is 1min on the sunrise and sunset curves. High range ambient light is recorded so data is usable for light curve analysis and behavioural studies (e.g. incubation if leg mounted) as well as threshold level geolocation. High sensitivity at low light levels allows detection of low Sun angles.

2. Temperature

See the individual logging mode details for temperature sampling and logging frequency. With Modes 1 and 3, temperature is sampled every 5minutes but only the maximum and minimum values are saved every 4hour interval.

- Range: -20'C to +40'C (maximum rating -40'C to +50'C)
- Resolution: approx. 0.5'C (1'C for models #65/#55/#50/#30, 0.125'C for C330 and any stalked model on request)
- Accuracy: +/-3'C (+/-5'C for #65/#55/#50/#30, +/-0.5'C for C330 and any stalked model on request)
- Note: sensor is located in the middle of the device (except for stalked model on request where sensor is on stalk). C330 temperature accuracy and resolution is sufficient for SST correlation.

What this means: Temperature data may be correlated with weather data, used to indicate flight at altitude and incubation, or used for general environment studies. Note, however, that direct Sun heating effects will elevate recorded temperature during daylight hours and the sensed temperature may also be affected by bird body heat.

3. Conductivity, wet/dry

Depending on logging mode, conductivity may be sampled. Some logging modes record wet/dry only with a count of 'wet' samples periodically recorded to memory.

- Range: approx. 20ppm-128000ppm*
- Resolution: 128 conductivity levels covering fresh, brackish, saline and brine
- Please note: this is only a crude conductivity measurement and values will vary with contacts' surface area and temperature. User must calibrate to obtain accuracy as required

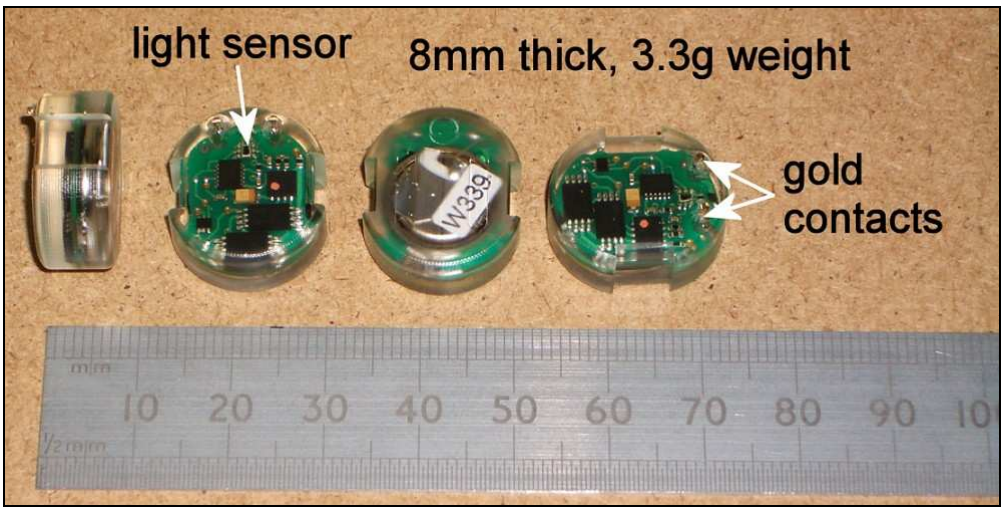
User can select whether conductivity as low as fresh water is included in the 'wets' count or whether to count only salt water. This makes the 'wets' activity record suitable for fresh water birds e.g. ducks, geese. For salt water species it may be sensible to exclude fresh water (default logger setting) in order to reduce the risk of false counts (e.g. rain, dew) but beware marine inhabitants of estuaries or glacial melt water where there may be low salinity 'sea' water.

What this means: Distinction between fresh, brackish water and seawater may help location fixing for waders (estuaries, lakes, rivers and sea have different

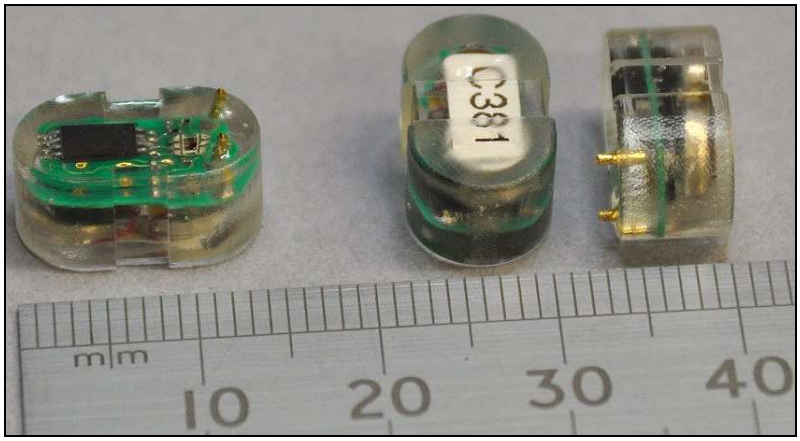
conductivities). Fresh water detection enables wildfowl and other water bird activity studies. 1hr 'wets' mode enables 1hr resolution for time of arrival of waders at water during migration hops. Beware that wets may be recorded if terminals are in contact with e.g. salty mud, wet-muddy feathers, regurgitated food, faeces as may be present in seabird nests and burrows.

* - Conductivity record is not compensated for temperature or dimensions of conductivity probes so range will vary.

4. Example models – many variations are available



Model: Intigeo-C330, 17x19x8mm, 3.3g, 2-3yr battery (e.g. seabird leg)



Model: Intigeo-C65, 14x8x6mm, 1.0g, 1-2yr battery (e.g. seabird/wader leg)

'Intigeo' = '**Inti**', the Incan Sun god + '**geo**', for geolocator.
It is pronounced '*in-tij-ee-oh*'.

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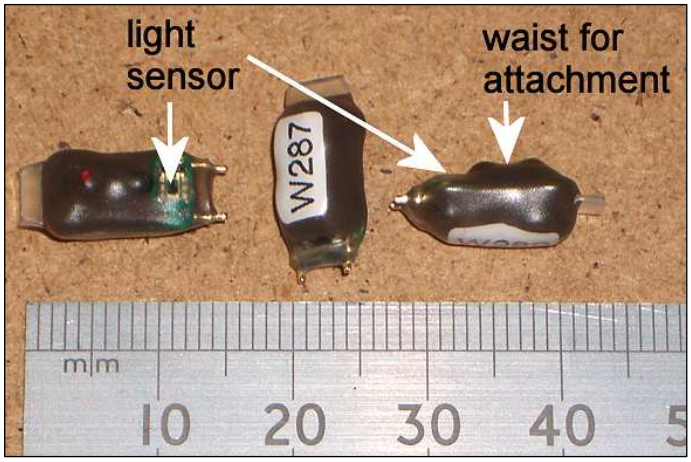
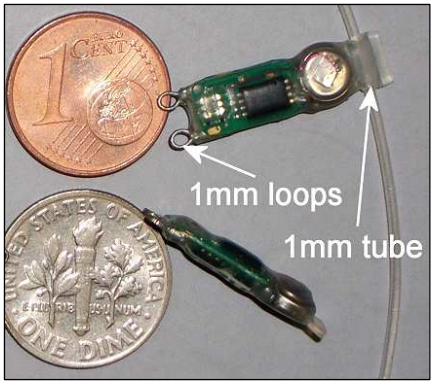
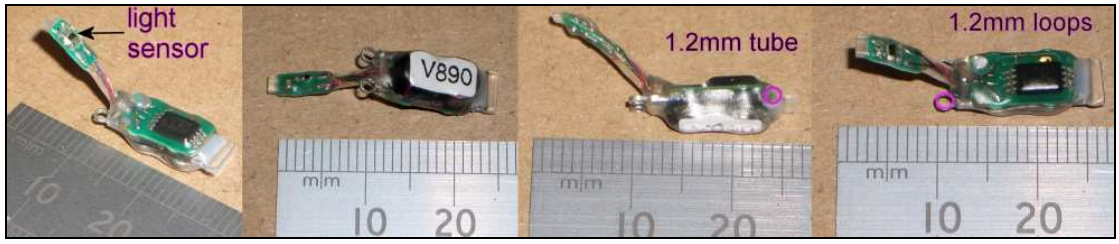


Model: Intigeo-W65A9-SEA
15x6x6mm, 0.7g, 1-2yr battery (e.g. wader leg)

Model: Intigeo-W55B1 (top), W55B9 (bottom)
20x6x3.5mm, 0.55g, 9-13month battery (e.g. swift back)



Model: Intigeo-P65C2-7 16x6x6mm excluding stalk, 0.74g, 1-2yr battery (e.g. passerine back)



Model: Intigeo-P65B1-11 15x6x6mm excluding stalk, 0.71g, 1-2yr battery (e.g. passerine back)

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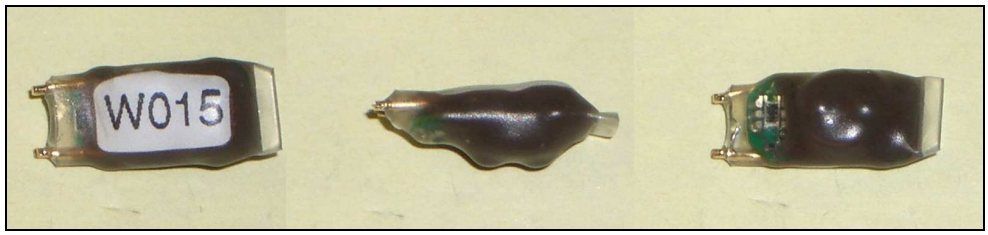
Model: Intigeo-P55B1-7 20x6x3.5mm excluding stalk, 0.60g, 9-13month battery (e.g. passerine back)

Model: Intigeo-W50B11-DIP 12x5x5.5mm, 0.48g, 9-13month battery (e.g. passerine back)

Model: Intigeo-W30Z11-DIP 12x5x4mm, 0.32g, 6-8month battery (e.g. warbler back)



Model: Intigeo-W30A9-SEA 12x5x4mm, 0.45g, 6-8month battery (e.g. small wader leg)

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5. Typical manufactured weights

	g		g
W30Z11-DIP	0.32	W65A9-SEA	0.70
P30Z11-7-DIP	0.36	P65B1-11	0.71
W50Z11-DIP	0.45	P65B1-7	0.72
W30A9-SEA	0.45	P65C2-7	0.74
W55B1-DIP	0.47	P50A22-14-SEA	0.75
W50B11-DIP	0.48	P65B1-14	0.75
P50Z11-7-DIP	0.50	P65A9-20	0.77
W55C9	0.53	P65C2-11	0.77
W50B11	0.54	P65C2-14	0.80
W55B1	0.55	P65A11-11-SEA	0.81
P50B11-7-DIP	0.55	P65A11-14-SEA	0.82
P55B1-7	0.60	P65C2-25	0.84
W65B1-DIP	0.60	P65A22-11-SEA	0.87
P50B11-7	0.63	P65C22-12	0.89
P50B22-11	0.65	C65	1.00
W65C1	0.67	C330	3.30

Other variations possible - let us know your requirements

Fitting an **Intigeo-W65A9-SEA** to the leg of a small seabird, copyright Maarten Loonen. The overlapping PVC leg ring is opened and slipped around the leg. The logger has already been wrapped with a small amount of stretched self-amalgamating tape to provide grip to the tie that passes through holes in the ring. The light sensor must not be obscured by the tape. If careful, a small amount of cyanoacrylate glue can be used to seal the leg ring.

6. Model ordering key

	Hard case (best for seabirds and waders)	
		very hard case, gold contacts, no loops, no tubes, no stalk nor light pipe
	C65	1.0g, est. 1-2yr battery life
	C330	3.3g, est. 2-3yr battery life, high accuracy temperature, twice memory of others
e.g.	**Softer case**	
P 65 A 11 -11 -SEA		
W 30 Z 11 -DIP		
	W	no light stalk nor light pipe; **minimum weight option**
	P	light stalk or light pipe fitted (not for leg mounting)
	30	6-8month approx battery life; **minimum weight option**
	50	9-13month approx battery life; battery mounted under logger (thicker, shorter)
	55	9-13month approx battery life; battery mounted at end of the logger (thinner, longer)
	65	1-2yr approx battery life
		Longer life means bigger battery which means more weight
	A	gold contact pins (no loops) seawater compatible (can be cut down)
	B	two loops at light sensor end for up to 1mm diameter harness cord
	C	two loops at light sensor end for up to 2mm diameter harness cord
	Z	thin wire contacts (no loops) unsuitable for seawater; **minimum weight option**
		2mm loops add more weight than 1mm loops; B,C and Z are not suitable for seawater
	1	tube at end opposite to light sensor for up to 1mm diameter harness cord
	2	tube at end opposite to light sensor for up to 2mm diameter harness cord (not for #50/#30)
	9	no tube; **minimum weight option**
		Number repeats if a second tube fitted at other end. 2mm tube is heavier than 1mm tube.
	-7	7mm 45degree optical light pipe
	-11	11mm light sensor on stalk (default angle approx. 30-40degrees) - not available for P30
	-14	14mm light sensor on stalk (default angle approx. 30-40degrees) - not available for P30
		A stalked light sensor normally provides the highest quality light data when back mounted
		(Angle of 20 degrees instead of 40 available on request.)
	<no suffix>	standard environmental protection casing
	-SEA	extra manufacturing steps increasing seawater protection (adds weight) (not for #50)
	-DIP	thin environmental case (usually sufficient for passerines); **minimum weight option**
		Note: a -11 or -14 stalk on a -DIP model will not be as strong as with a standard case
e.g. Intigeo-P65A11-11-SEA (11mm light stalk, 1-2yr, gold contacts, 2x1mm tubes, e.g. seaduck)		
e.g. Intigeo-W30Z11-DIP (no light stalk/pipe, 7month, thin wire contacts, 2x1mm tubes, e.g. warbler		
Not all combinations are possible or advisable - please enquire		

7. How do I attach the Intigeo to the bird?

Attaching anything to a wild animal can have significant adverse effects on survival, reproduction, energetics or behaviour. It is the responsibility of the field researcher to have secured all local bird handling, capture and tagging permissions required to carry out geolocator studies and to also have performed an impact assessment concerning these aspects. We recommend that you consult your local regulatory body and/or ethics committee. Studies must be conducted in accordance with institutional, national and international guidelines concerning the use of animals in research and/or the sampling of endangered species. Migrate Technology Ltd accept no liability for the use or misuse of any of the suggested attachment methods and recommend that small scale acceptance trials are performed before any large scale study.

Attachment method depends on the species of bird and must be carefully considered. You should be very familiar with your chosen study species and, if you are not, then you should learn about its behaviour and physiology as thoroughly as you can to determine the optimum tag attachment method. Only permitted trained bird handlers should handle wild birds. To learn from work already undertaken, a review of relevant published geolocator studies should be performed before any practical use commences.

Considerations are similar to those explored over a number of decades using VHF tags. One difference is that geolocators usually need to be attached for at least a year to be useful. VHF tags were often attached with the intention that they fall off after a small number of months, but the aim with geolocators is for them to stay attached for longer. It is possible that birds may have geolocators attached for many years, particularly if site fidelity is low or a study ends. Assessment is therefore complicated by possible deleterious effects accumulating over consecutive years. Unlike VHF tags, geolocators do not have an antenna.

An initial trial study should be performed if considered advantageous. A behavioural observation of birds in captivity is another option to be considered as is the testing of attachment methods with a cadaver of the species.

8. Which Intigeo should I choose?

The first step to determine the optimum model is usually to consider the body weight of the species to be studied and decide the maximum weight of logger acceptable to you. This is because, generally, the heavier the logger, the greater its functionality. The weight of logger to be used is a decision to be made by the researcher using their knowledge of the species with guidance from a relevant ethics committee. When leg mounted on seabirds and waders, a maximum weight of 1-2% is often considered. For passerine ‘back pack’ mounting, a maximum weight of 3-4% is often considered.

Generally, geolocators are mounted on the leg or as a back pack. In all methods, obscuration of the light sensor on the geolocator should be kept to a minimum in order to maximise the quality of data. For back mount, near field shading comes from plumage (and folded wings) and vegetation. For leg mount, near field shading can come from the body of the bird and light will be somewhat blocked if the bird is sitting or has its logger leg tucked up. Rather than being wholly problematic, these complexities can create behavioural data such as for incubation.

When assessing weight acceptance, remember to include the weight of the attachment materials. Now that our devices are so small, this can be significant.

Seabirds and waders

Leg mounting is invariably used for seabirds and is usually the method for waders. Often, a 1% body weight loading for leg mounting is regarded as acceptable for many seabirds and waders with 2% sometimes considered a maximum. Other factors that should be considered include leg length and thickness, positioning on the leg (tibia or tarsus), interference with the tibia-tarsal joint (is a spacer necessary?), torque on the leg (i.e. keep the centre of gravity of the attachment as close to the leg as possible), potential damage to eggs during incubation, potential damage and wear from rocky habitat, and obscuration of the light sensor by thigh feathers.

A number of different methods can be used to attach electronic tags to the leg but they generally involve attachment to a plastic leg ring or leg 'flag' (this made of special ring PVC plastic; Darvic now appears to have been replaced with Salbex). This plastic can be shaped when heated (boiling water can be hot enough) but there are a number of suppliers who will make rings to order. The mounting ring should not be much shorter than the logger and can be longer. Short rings apply greater pressure to the leg and are more likely to cause chaffing.

UV stable nylon cable ties (with stainless steel barb) are commonly used as a quick fit for larger loggers (e.g. C65, C330) on plastic rings but for smaller loggers, another solution is necessary. Certain types of thread, cord or fishing line are some materials used for tying, and are often given a protective coating of adhesive to prevent movement and so reduce the risk of detachment. A couple of layers of stretched self-amalgamating tape (use minimally) around the logger, under the tie or cord, can aid grip and 'bite' of the attachment, particularly if a cable tie is used. Even stainless steel barbed cable ties have been known to loosen very slightly over time so this tape can be important in reducing the risk of the tightened tie falling off. Do not fit too much, as this may encourage barnacle growth and increases the chances of obscuring the light sensor. If using a cable tie, use of the proper cable tie tightening tool is recommended. With a suitable application of a plastics cyanoacrylate adhesive followed by a suitable epoxy resin, W65A9-SEA loggers have been successfully fitted without additional cord or ties.

Harnesses are generally viewed as harmful to seabirds and should be considered with great caution. Harnesses have been used successfully for some species of wader although other species are unsuitable. Unsuitable species include those where weight gain is attained by fat being laid down where a harness would fit. Many migratory birds have considerable weight gain and loss during the year.

For seabirds and waders, where weight will allow, we suggest the C330 or C65. Being hard cased, they cope better with wear and tear. If the C65 is too big or heavy, then we suggest the W65A9-SEA or, with a much shorter life, the W30A9-SEA. The C65 is not capable of SST measurement.

Songbirds

A leg-loop (figure-of-8 or Rappole-Tipton) harness is typically used with most songbirds. Choice of harness material varies. Some researchers prefer an elastic material (e.g. 'Stretch Magic') and others non-elastic (e.g. UV-stable nylon mist net repair braid). Some fit an elastic cord within an outer non-elastic sheath. With a suitable model, the harness material can be passed through the Intigeo tube, around the thighs, and knotted to the metal loops. A dab of cyanoacrylate glue (or whatever is suitable for the harness material) should be put on the knots and ends of tube once in place, to prevent movement and untying. It is usually best if the harness cord is not able to move through attachment points once deployed as this may cause detachment through abrasion, or the tag to become twisted.

We cautiously mention here the 4% body weight loading limit sometimes suggested for back pack mounting but note that suitability should always be assessed for the particular species. (Cochran, W.W. (1980). Wildlife telemetry. In Wildlife Management Techniques Manual, 4th edition (S.D. Schemnitz, ed.), 507-520. Wildlife Society, Washington.)

For most passerines and other birds where a back mount is sensible, the stalked P## are suggested. The W## loggers can also be used when necessary but feathers or folded wings may obscure the light sensor reducing the quality of light data. For the -11 and -14 P## variants, a posterior pointing light sensor on a stalk is fitted. The aim is to select the most suitable length in order that it just protrudes above the plumage and folded wings (to minimise sensor shading variation but not to significantly increase aerodynamic drag). The length of the stalk is chosen to suit the species. The -7 P## devices are fitted with an optical light pipe. The disadvantage over a stalk is that this reduces sensitivity a little and is still a little vulnerable to plumage shading variation at the sides. The aim of light level geolocation is to gather light data with as little shading variation as possible; this does not necessarily imply the highest light exposure.

Rear mounting loops and a front tube are options to enable easier harness attachment. When choosing a stalked model, consider the species' life style and behaviour e.g. caution with cavity nesters where a stalk may interfere with entry/exit.

For some very aerial birds, e.g. swifts and swallows, data of good quality has been obtained from back mounted loggers without stalks e.g. W##B1, especially if mounted far forward on the bird (with suitable 'body' harness as different from the Rappole-Tipton leg-loop figure-of-8 harness). The loop and tube option is available to aid connection with your harness cord. The W55 has the advantage of being thinner which is better for cavity nesters and minimises aerodynamic drag with these types of bird.

If you like, when you have decided your maximum acceptable logger weight, tell us this and the species, along with any preferences regarding loops/tubes or stalk, and we will try to give you sensible options around that weight.

9. How long will the Intigeo record?

The C330 has battery capacity for 5yrs but field use has shown that attrition in seawater is significant and if used on seabirds, typically 2-3yrs should be expected. The #65 has a two cell battery that should have a life between one and two years from the time of manufacture. However, the internal memory may fill before the batteries expire depending on the mode you select when you start them logging and the behaviour of the bird.

The #55 and #50 have a single cell and less battery life. Field data has shown that these batteries usually last for 9-13months with the devices lasting the longest in cooler climates.

The #30 also has a single cell but is smaller. Field data has shown these usually last 6-8months.

Higher temperatures accelerate the discharge rate of a logger's internal battery which is why we recommend that they are kept asleep (logging stopped) and at refrigeration temperature (e.g. 5'C) when not in use. Our ratings for battery life are based on 25'C ambient temperature. Where they are exposed to higher temperatures for long periods, battery life will be reduced. Approximate lifetimes indicated are from the date of delivery.

10. What happens if the Intigeo is dead when I retrieve it?

Sometimes loggers do fail prematurely, most often due to wear and tear, shock or associated sea water ingress and corrosion. Also, they are often retrieved after the battery has naturally expired. The data recorded up until the point of failure will have been stored in a permanent memory that is usually extractable if returned to us. If corrosion or damage is extensive, the memory may not be recoverable.

11. Other necessary items

The Intigeo-IF interface unit allows communication with a computer running Microsoft Windows. This is essential as Intigeos are shipped asleep (not logging) and must be started prior to deployment. The interface is also used to download the data. Interface software is supplied with the IntigeoIF unit and data is saved in time-stamped tab delimited ASCII files.

12. Summary of user programmable recording modes

Values in red indicate the limiting parameter for a single deployment.
Further mode details are supplied with the user manual.

W30/P30 recording modes (using light Range 4) - user selectable at start of logging

mode	full light range	clipped light range	+/-3'C temp	cond	wet/dry	recording duration* (months)	est batt life (months)	notes
1	5min		■	■	30s->4h	15	7	all sensors for general 1yr use
2			■	■	30s->5m	2	11	T, C and wets only - no geolocation
3	5min		■	■	30s->1h	15	7	as 1 with limited wet/dry
6		5min			30s->10m	26	7	longest 5min record mode
7		5min			6s->5m	24	6	as 6 with higher wet/dry time res
8					6s	30	7	wet/dry only - no geolocation
9	5min				6s	10	6	for short seabird deployments
10	5min					24	7	longest full range 5min light record
11	10min				30s->10m	24	7	reduced time resolution in light

W55/P55/W50/P50 recording modes (using light Range 4) - user selectable at start of lo

mode	full light range	clipped light range	+/-3'C temp	cond	wet/dry	recording duration* (months)	est batt life (months)	notes
1	5min		■	■	30s->4h	15	11	all sensors for general 1yr use
2			■	■	30s->5m	2	11	T, C and wets only - no geolocation
3	5min		■	■	30s->1h	15	11	as 1 with limited wet/dry
6		5min			30s->10m	26	11	longest 5min record mode
7		5min			6s->5m	24	10	as 6 with higher wet/dry time res
8					6s	30	11	wet/dry only - no geolocation
9	5min				6s	10	9	for short seabird deployments
10	5min					24	11	longest full range 5min light record
11	10min				30s->10m	24	11	reduced time resolution in light

C65/W65/P65 recording modes (using light Range 4) - user selectable at start of logging

mode	full light range	clipped light range	+/-3'C temp	cond	wet/dry	recording duration* (months)	est batt life (months)	notes
1	5min		■	■	30s->4h	15	23	all sensors for general 1yr use
2			■	■	30s->5m	2	23	T, C and wets only - no geolocation
3	5min		■	■	30s->1h	15	23	as 1 with limited wet/dry
6		5min			30s->10m	26	23	longest 5min record mode
7		5min			6s->5m	24	21	as 6 with higher wet/dry time res
8					6s	30	23	wet/dry only - no geolocation
9	5min				6s	10	19	for short seabird deployments
10	5min					24	23	longest full range 5min light record
11	10min				30s->10m	24	23	reduced time resolution in light

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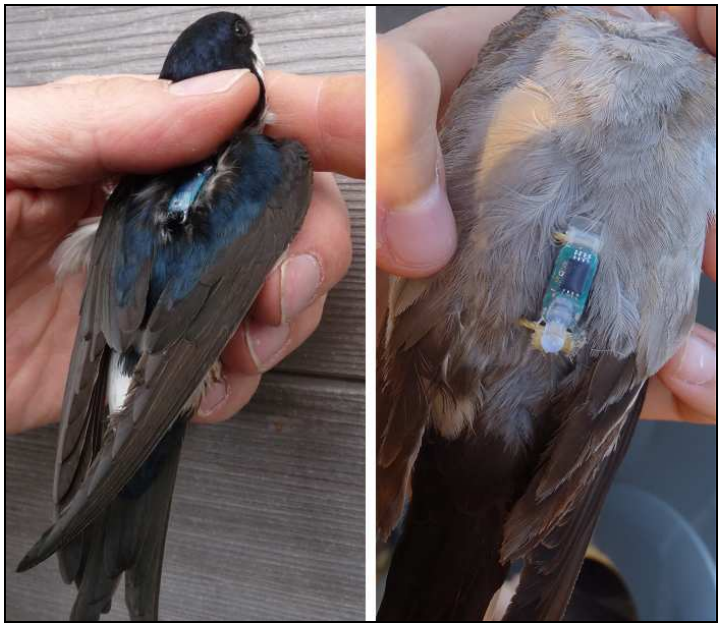
C330 recording modes (using light Range 4) - user selectable at start of logging

mode	full light range	clipped light range	+/- 0.5'C temp	cond	wet/dry	recording duration* (months)	est batt life (months)	notes
1	5min		■	■	30s->4h	30	60	all sensors for general 1yr use
2			■	■	30s->5m	4	60	T, C and wets only - no geolocation
3	5min		■	■	30s->1h	30	60	as 1 with limited wet/dry
6		5min	♦		30s->10m	52#	60	longest 5min record mode
7		5min	♦		6s->5m	48#	60	as 6 with higher wet/dry time res
8			♦		6s	48	60	wet/dry only - no geolocation
9	5min		♦		6s	20	60	for short seabird deployments
10	5min					48	60	longest full range 5min light record
11	10min		♦		30s->10m	48#	60	reduced time resolution in light
12	1min		5min			6	60	chronobiology - not for geolocation
13	5min		5min			14	60	chronobiology - not for geolocation
14	5min		15min			26	60	chronobiology - not for geolocation

- for very aquatic species, the wet/dry/temperature recording duration may be much reduced

♦ - max,min,avrg immersion temp saved every 4hrs (SST use) - temp sampled each 20mins continuous wet only

All durations estimates. Battery endurance reduces at elevated temps. Activity affects memory usage rate.



Left: **Intigeo-W55B1** (thin package, 1mm loops and tube for harness mounting) copyright Lyndon Kearsley. Right: **Intigeo-W65C2-7** (2mm loops and tube used with leg loop harness) copyright Alex Jahn.

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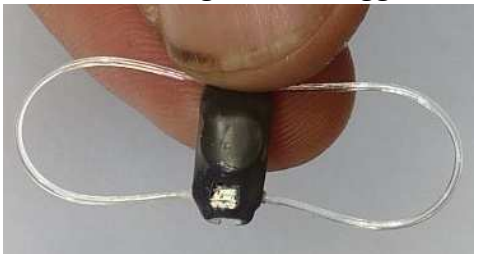
13. Other notes

No harness or attachment materials are supplied with the logging devices. Migrate Technology Ltd provides IntiProc software to enable light to location conversion using the threshold method. This software is free to our customers and acts as a user friendly front end to the open source R package GeoLight. Data is recorded in ASCII files suitable for most geolocator analysis tools e.g. the R tools GeoLight, FLightR, SGAT, tripEstimation, MultiTrace from Jensen Software,and TAGS.

Intigeo-W30Z11-DIP (0.32g) on Pied Flycatcher using 'Stretch Magic' harness cord. This Intigeo model is made with two 1mm tubes under the logger. After starting the recording, the two logger contacts were cut off. A suitable length of 'Stretch Magic' was cut, pushed through the tubes and the ends then hot melted together to bond. This formed a figure-of-8 leg-loop (Rappole-Tipton) harness. The loop was then rotated until the bonded ends were inside one of the tubes. A small drop (e.g. using pencil tip) of superglue was then applied to the end(s) of this tube and, by capillary action, was drawn inside, securing the loop. This ensures a minimum weight attachment. By using stretchable harness cord and preparing in advance, bird handling time is minimised (assuming the loop is the correct size for the individual). For this study it may have been advantageous to add a light pipe to the logger to increase data quality but the extra weight and aerodynamic load may have made it unsuitable for this very light weight species. Note also that the orientation of the logger in order to obtain minimum light sensor shading from feathers/wings may not be obvious and may vary between species (and logger models). When you recapture birds, take careful note (or a photo) of how much the sensor is shaded; the manner in which the bird's plumage has settled around the logger may have changed significantly from when deployed. This could help you interpret the data, and help you decide a better mounting technique for next time. Photos by Bryan Thorne, David Price and Malcolm Burgess.



We do not guarantee function against wear and tear or misuse. With some species and habitats significant wear or abrasion can occur leading to premature failure of the device (particularly in a seawater environment). Do not expose to mechanical vibration (e.g. electrical power tools) or to

temperatures outside the range -40 to +50'C. Malfunction may result from physical shock, vibration and high levels of electrical or electrostatic interference.

Please contact James Fox (james@migratetech.co.uk) with any queries you may have. Specifications may change.

Disclaimer