



SeaTag-3DS

PSAT Tag for Spawning Event Detection and Reporting

Addendum to the SeaTag-SAM / SeaTag-3D Manual

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European eel released into trout farm holding tank (raceway) on Flores Island (Azores) following pinger implantation and SeaTag-3DS PSAT attachment. Credit: Sune Riis Sorensen, DTU.

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About This Manual

SeaTag-3DS is a superset or a specialized version of our model SeaTag-3D, itself a member of the SeaTag-SAM family of PSAT tags targeted at Stock Assessment and Mortality. The -3DS model is primarily intended for spawning detection, localization and reporting in fish. Yet it might also serve other purposes, such as the detection of pinger implanted prey fish (salmon) nearby when mounted on a predator species (killer whale). It includes all the capabilities of the -3D model, but adds a detector for industry standard JSATS pingers and firmware that evaluates pinger detections to identify possible spawning events.

This manual serves as an addendum to the SeaTag-SAM manual. As such it focuses specifically on the spawning detection method and operating procedure. This manual references the SeaTag-SAM manual as needed and these references are highlighted with a blue background for clarity.



A set of SeaTag-3DS (on table) are modified in preparation for connecting the specialized eel attachment lanyard (yellow assemblies on table). December 2025. From left, Kim Aarestrup, Sune Riis Sorensen and Vincent Neron all of DTU.

1. Concept and History of the SeaTag-3DS “Spawning Detector” Tag

The history of SeaTag-3DS dates back to around 2017, when Rick Goetz of NOAA’s Manchester Research Lab was interested in methods to detect spawning in sablefish. This would be one component of research to establish if sablefish in the Pacific are single or multiple distinct populations, a determination that is important for the management of this commercial fishing stock.

In response to a NOAA SBIR solicitation, Desert Star Systems proposed a concept in which a small acoustic pinger would be implanted in the oviduct or ovary of a target fish. An external PSAT which integrates a small acoustic detector listens for the pinger signals. As the fish spawns, the pinger is ejected with the spawn. And as the fish moves on, the pinger signal is lost. A sustained loss of the pinger signal serves as an indication of possible spawning. The PSAT now releases from the fish and floats to the surface. Here, the occurrence of this event along with the associated sensor measurements such as for depth and temperature at the time of the event is reported via the Argos satellite constellation. Further, the transmission of ‘daily summary’ packets covering the period since tagging provides daily geo-position measurements, depth and temperature histograms and sensor snapshots to illuminate the migratory history leading to the possible spawning event.



Figure 1: Spawning event detection concept. Left: An external PSAT tag (SeaTag-3DS) detects the acoustic pings from a JSATS pinger implanted in the fish ovary or oviduct. Center: As the fish spawns, the pinger is ejected with the spawn. Right: When the fish departs and the pinger signal is no longer detected by the PSAT, it separates from the fish and rises to the surface to report the time, location and circumstances of the possible spawning event.

By 2019, Desert Star had developed two versions of a spawning detector PSAT: The small SeaTag-3DS with a simple pinger signal presence/absence detector. And a plug-in ‘payload section’ for the modular and more capable but also larger SeaTag-MOD. The SeaTag-MOD detector can not only detect but also decode the JSATS pinger signal, such as to receive fish internal temperature that is transmitted by some of these pingers. Or even identify nearby fish with an implanted JSATS pinger by the ID code of that pinger.

Following Desert Star’s independent engineering in-water tests, the first fish-involved testing happened at Manchester Research lab. Here, a SS400 JSATS tag was injected in the oviduct of a sablefish that was

subsequently placed into a small tank. A SeaTag-MOD with the JSATS pinger detector floated nearby and successfully detected the repeated pinger transmissions in an overnight test.



Figure 2: A SeaTag-MOD PSAT equipped with a JSATS signal detector ‘payload section’ floats near a sable fish with an injected ATS SS400 JSATS tag in a tank at NOAA’s Manchester research lab



Figure 3: Rick Goetz (left), Andy Jasonowicz (center) and a third team member study the data return from the overnight fish test. Notice the tag to the left of the computer is linked to a docking station to recover a detailed report. To the left of the tag is the Pinger Dish from ATS (the blue box), which is used to activate the company’s JSATS pinger and set the Ping Repeat Interval (PRI) which determines the battery life of the pinger.

Lacking project funding for tests in fish pens and then the ocean, the “Ovolutag” / spawning detector technology subsequently rested. In late 2022 a team at Denmark Technical University (DTU) led by Sebastian Politis (PI) received a grant to tag European Eel in order to monitor their long hypothesized but never firmly established migration and subsequent spawning grounds in the Sargasso Sea. The European Eel is a unique and very challenging subject for spawning detection, due to the extremely distant and long migratory journey, and the fact the fish’s ovary only develops once their migration to the spawning grounds has started. Not finding reproductive organs, ancient Greek philosopher Aristotle famously proposed that eel were spontaneously generated from the earth’s guts.

DTU conducted several tests with captive eel, including testing if a pinger would indeed be ejected at the time of spawning, and testing if relatively small eel (minimum size limit 1.3 kg) could indeed carry a ~60g tag on such a long journey.

Ultimately, eel fishing, captive field testing and then tagging and release into the ocean commenced in December of 2025 on Flores Island in the Azores archipelago. The eel’s journey from Europe to the Azores had already been well established through prior satellite tagging, and so this known migratory way station provided the shortest distance to the Sargasso Sea. And therefore, the highest probability to remote observe the rest of the migration and spawning in the Sargasso Sea. Or elsewhere.

This addendum manual describes the tagging procedure using the DTU project as an example. It is important to emphasize here again that the DTU project represents the very first use of the ‘spawning detector’ technology in the wild, and that this journey only has just begun. While available as a commercial product, SeaTag-3DS must therefore nonetheless be considered an experimental device at the time of this writing.



This manual is written on purpose in the form of a sort of log of the events of the DTU project and expedition to the Azores. Lacking as of yet established community knowledge on best use practices, capabilities and limitations for SeaTag-3DS, this format is intended to guide the reader through a series of steps from which you might derive your own experiment design.

Figure 4: PI Sebastian Politis welcomes a truck load of pinger-implanted and PSAT-tagged eel to the beach at Lajes in advance of a night time release on the island of Flores, Azores. Each fish is individually transported in its own plastic bin to prevent any entanglement of eels and their tags.

2. Experiment Preparations and Tagging

The listed steps involved in experiment preparation, tagging and release are reviewed in the following sub-chapters.

1. **Pinger selection:** A suitable pinger is selected. Pinger size, shape, suitability for ejection with spawn, battery life and ping repeat interval (PRI) available to achieve the required battery life are selection factors.
2. **Preparation Activities and Tests:** The tag attachment mechanism is developed. The pinger implantation method is tested. Captive tests on fish involving the pinger and either a dummy or a life PSAT tag are conducted.
3. **Pinger and Tag Configuration:** Tag configuration parameters and the pinger PRI rate are set based on the outcome of the preparatory tests and other insights and data or paper reviews.
4. **Pinger and Tag Activation:** The pinger and SeaTag-3DS are activated and the first pinger signal detection is monitored. The monitoring may be done before or after the pinger is implanted in the fish and SeaTag-3DS is attached. Each method has its own advantages.
5. **Data Return Monitoring and Spawning Event Evaluation:** The Argos satellite returned data is monitored. Fish migration, behavioral characteristics and ultimately the probability that a reported pinger signal loss event is due to spawning is evaluated.



Figure 5: Above Lajes harbor and beach on Flores Island, where the eels were released

2.1. Pinger Selection

SeaTag-3DS is compatible with JSATS pingers that operate at 416.7 KHz. JSATS stands for the Juvenile Salmon Acoustic Tracking System. It is an open industry standard developed for the U.S. Army Corps of Engineers, and initially applied to salmon tagging related to the dams and hydropower installations in the rivers and reservoirs of the U.S. Northwest including the Columbia River.

The high operating frequency allows for very small pinger designs including models that are suitable for implantation into a fish by injection. The pingers are mostly used in fresh water because their high frequency pings experience significant absorption in sea water, limiting their detection range to around 100 meters. Yet, for spawning detection only a short distance of generally less than 1 meter between the tag in the fish and the external SeaTag-3DS must be covered. Consequently, this frequency choice is appropriate and the resulting small pinger size advantageous.

SeaTag-3DS should work with 416.7 KHz JSATS pinger from any manufacturer. However, it is still advisable to test tag type compatibility early in the design process. In particular because pinger size, form factor and outer coating may influence the probability that a pinger is ejected with the eggs to provide a spawning signal. But also to firmly establish the overall acoustic and engineering compatibility with SeaTag-3DS.

We have tested SeaTag-DS with the JSATS pingers made by ATS. Important selection criteria are the battery life, which in turn depends on the selected Ping Repeat Interval (PRI). And the size and shape of the pinger with corresponding implications for minimum fish size and the probability that the pinger is ejected with the spawn.

The following table provides the weight and battery endurance for several ATS manufactured JSATS pinger models. Please refer to the [ATS web site](#) for a detailed description of each pinger. Specifically at the time of this writing, look for their SS400 and SS300 series acoustic pingers.

Pinger Model	Weight (g)	Size (mm)	3 sec PRI (days)	10 sec PRI (days)	90 sec PRI (days)
SS410	0.21	15.0 x 3.3	48	111	222
SS420	1.0	17.5 x 6.3	108	247	484
SS440	2.2	20.0 x 8.5	302	694	1372
SS300-337	0.3	10.7 x 5.0 x 2.8	23	68	267
SS300-379	0.43	11.9 x 6.3 x 3.7	45	136	592
SS300-392	0.965	14.4 x 8.5 x 5.3	81	240	951

Notes:

- Weight, size, and battery endurance at 3 sec and 10 sec PRI is per ATS SS300 and SS400 datasheets at the time of this writing.
- Battery endurance at 90 sec PRI is extrapolated from the 3 sec and 10 sec points using straight-line extrapolation.

Figure 6: Weight, Size and battery endurance for several ATS manufactured JSATS pingers

Here are several notes from the DTU project and in general regarding pinger selection and procurement:

1. **PRI:** We used a 90 sec PRI in the DTU project to maximize battery life in anticipation of a long eel migration journey. While the pinger supports PRI up to 99.9 seconds, we experimentally determined that 90.0 sec is the longest 'reliable' PRI due to the inherent pinger specific variations of the PRI, and PRI cross checking in the ATS Pinger Dish that overflows at 100 seconds. Shorter PRI may be advantageous when the time to expected spawning is limited and determining the exact time and location of spawning is the priority. See section 2.3 for details.
2. **Projected Battery Life:** A prematurely expiring pinger battery might be mis-interpreted as a spawning event. Therefore, it is prudent to apply a safety margin. DTU used the SS410 and SS440 pinger. Tags equipped with the SS410 pinger (222 days nominal live at 90 sec PRI) were programmed for a timed pop-up due to non-spawning after 182 days, a safety margin of about 18%. SS440 pingers with a nominal battery life of 1372 days at 90 sec PRI were programmed for pop-up after 730 days, for a safety margin of 47% (the SeaTag-3DS battery and the maximum expected time to spawning were the limiting factors here).
3. **Verifying Pinger Battery Life at the Time of Spawning:** Activating an additional pinger at the time of tagging, and keeping it in storage at a temperature similar to the average temperature the implanted pingers are expected to see may be a good strategy! Once signal loss events are remote reported, by SeaTag-3DS after pop-up, the retained pinger can be checked to see if is still pinging. This information can be used to decide if a signal loss event is more likely to be associated with spawning, or with pinger battery depletion.
4. **Procurement of ATS JSATS Pingers from ATS or DSS:** This issue comes up during equipment procuring for your tagging project, and until now our recommendation has been that you can do it either way. However, since the DTU project, our *recommendation* is that you purchase the pingers from DSS. The cost will be higher, but it gives us an opportunity to test each pinger with an associated SeaTag-3DS. This additional quality assurance step removes the failure potential that a pinger might not work correctly or is somehow not compatible with SeaTag-3DS. We will also set the PRI as needed for your project and ship the pinger already activated or still in the off state for your project. This either simplifies or eliminates the need of pinger activation and configuration with your own Pinger Dish device.

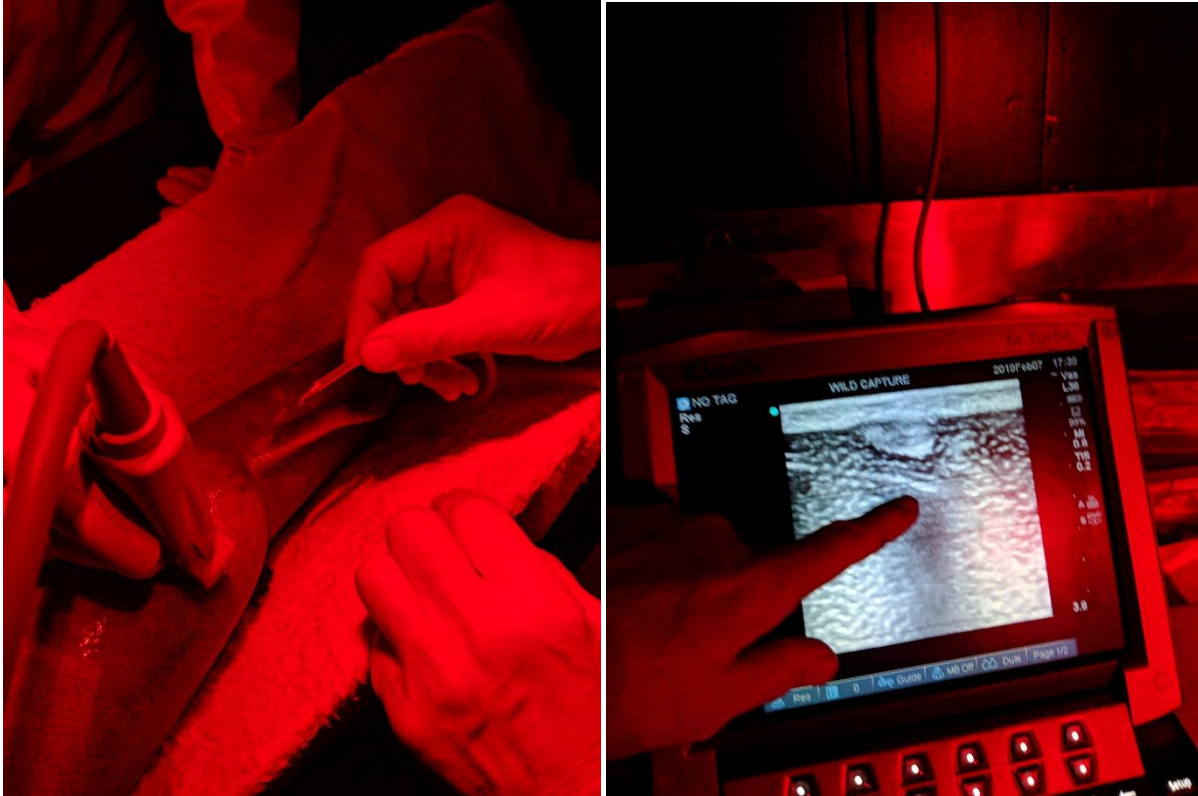


Figure 7: Pinger implantation methods vary. These pictures show the method of injecting a small SS410 pinger in the oviduct of a sablefish (Rick Goetz, NOAA Manchester Lab). The pinger is partially inserted into a length of surgical tubing, which is attached to a syringe. Pinger insertion is monitored with an acoustic imaging system. Once in the desired location, the plunger of the syringe is pushed to eject the pinger from the tube and the tube is removed.

The DTU team used a surgical method to implant the larger SS440 pinger in eel.

2.2. Preparation Activities and Tests

Preparations should start with plenty of time before the scheduled tagging so that any challenges can be worked through and corrected. Here is a list of recommended preparations, modelled on the tests that the DTU team worked through. Some of this happened at their lab and eel pen in Denmark, and some of it on Fores Island prior to tagging.

1. **Pinger compatibility and ejection:** The team tested both the SS410 and the SS440 pinger in eel. The eels were treated with hormones to induce the silvering and spawning, and it was observed if the pinger would be ejected. The results were good for the smaller SS410 pinger, but the larger SS440 pinger was at times embedded in tissue and therefor not ejected during spawning. This did present a conundrum, in particular since the battery endurance of the smaller SS410 is thought to be often insufficient for the fish to reach the spawning grounds. Given various uncertainties however, some fish were implanted with the SS410 pinger, and more with the SS440. The reasoning for the use of the SS440 was eel tend to die quickly after spawning. This also will result in a loss of pinger signal, albeit on grounds of mortality. But it would still reveal the approximate spawning grounds.



Figure 7: ATS JSATS Pinger Models SS440 (left), SS300-337 (center), SS410 (right) shown here roughly to scale. The graduations are in cm.

2. **PSAT tag carrying capacity and minimum fish size:** DSS can provide dummy test tags to evaluate size compatibility with fish. These tags have the same size and weight as a standard tag, but they lack the electronics or have non-functioning electronics (reject tags). After a series of tests with eels carrying SeaTag-3DS and smaller alternatives (without the spawning detector capability), DTU found SeaTag-3DS suitable but defined a minimum host fish weight of 1.3 kg.
3. **External tag attachment harness:** Tags shedding early is a common problem for PSAT. Yet, for SeaTag-3DS, good tag retention is essential to observe a spawning event. Tag attachment is highly species specific. Ideally the harness and method will be based on what has been tested before and has demonstrated to provide a sufficiently long tag retention. This project used a method developed by Kim Aarestrup and validated in prior PSAT tagging of European eels. The attachment consists of three medical grade stainless steel wire loops, which are inserted through the fish's skin and tissue just forward of the beginning of the dorsal fin. Each of the three wire

loops is connected to its own attachment point of a small harness. Figure eight shows the yellow loop (front), the forward loop of a stainless steel, red shrink tube covered linkage (center), and the aft loop of the same linkage (rear). When the fish is swimming and the tag pivots back parallel to the eel's body, the front attachment first serves as the anchor. If it starts pulling out, force is shifted to the center loop, and after that to the rear wire loop. The drag force may also be split to some degree among the three wire loops. Wires are bent over to prevent sharp edges, and stubs are covered with shrink tubing. Shrink tubing and epoxy are also used cover and secure knots in the white rope that connects to the release mechanism nose cone at the bottom of the SeaTag-3DS tag.



Figure 8: A three-point attachment harness extends the retention period for the external tag. The release or bottom nose cone of SeaTag-3DS is at the very bottom of this picture.

- 4. Simulated Spawning Event Test:** Discerning a potential spawning event requires that the detection of the pinger signal is sufficiently reliable. SeaTag-3DS does evaluate a series of three pings to avoid confusing any ambient noise with a pinger signal. And the algorithm checks for pinger signal loss several times in a row to prevent temporary signal fading to be mis-interpreted as a permanent signal loss; a possible spawning event. The DTU work included a series of fish-involved field tests that was used to define the pinger detection parameters and evaluate the reliability of ping detection and noise rejection using these parameters.

However, we recommend that you evaluate the reliability of the settings for your experiment through a simulated spawning event test. This experiment is best done with a dedicated SeaTag-3DS test tag. The tag is standard, except that the igniter of the one-time-use kinetic release mechanism is not equipped so that you can do repeated tests if needed. The test is straightforward.

1. The pinger and test tag are activated (see section 2.4).
2. The pinger is implanted in the fish and SeaTag-3DS is attached as planned for the study.
3. The fish is now released into a captive environment. Ideally this is a fish pen. We did not have this available for the DTU work, so the test eel was instead in a net that was lowered into a lake. This test should **not** be done in a small tank because the acoustic environment is too different from open water. A larger in-ground pool or basin may work because this allows acoustic energy to dissipate into the ground.
4. The test duration should cover at least 100 pinger detection intervals. If that is not possible at the standard pinger detection interval (see section 2.3), a test tag can be configured with a much shorter ping detection interval and PRI to shorten the test. For the DTU work, the test tag checked for the pinger signal once per minute, compared to once every four hours in the actual experiment. The PRI was set to 16 seconds instead of 90 seconds to complete a three-ping detection in less than one minute. These settings meant we could limit the test to two hours, evaluating 120 detection events.
5. The SeaTag-3DS is now removed from the fish so that the pinger signal is lost. This is the simulated spawning event.
6. SeaTag-3DS is now placed under an open sky, allowing it to Argos transmit.
7. The Argos data return is obtained. This includes a 'spawning event packet' that includes the necessary data to evaluate the reliability of spawning detection.

Experiment Evaluation Method

Following the detection of a **Pinger Detection Signal Loss** event, SeaTag-3DS transmits a data packet named SDPT_3DPDSL2 (**SeaTag Data Packet Type _ 3D Pinger Detection Signal Loss version 2**) every 20th transmission. This packet is normally used in combination with other data returns to evaluate if a signal loss is due to a spawning event. For the test, some of the data fields are used to estimate the reliability

of spawning detection. For the DTU work, the goal was a probability of one erroneous signal loss detection per 100 years of operation.

PD_COUNT: This data field reflects the total number of pinger detection attempts. This counter increments every 16th attempt. So, you will see numbers of 0, 16, 32, 48 and so on. Look for at least 100 attempts to consider your test valid.

PD_PCTOK: The percentage of pinger detection attempts that were successful prior to the continuous sequence of non-detects that led to the signal loss declaration. This can range from 0% to 100% in 1% increments.

PD_RMAX: Maximum continuous sequence of failed pinger detection attempts before the sequence that led to the signal loss declaration.

For the DTU lake test with the captive eel, PD_COUNT was 149 and therefore above our goal of 100 minimum. PD_PCTOK was 66%. PD_RMAX was 4 sequential failed pinger detection attempts.

For final experiment settings of 12 successive non-detects to declare signal loss, and one pinger detection attempt every 4 hours, we arrive at the following:

- Probability of 12 successive non-detects (erroneous pinger signal loss detection): $(1-0.66)^{12} = 1:419037$. At one pinger detection attempt every 4 hours: $419037 \times 4 = 1676148$ hours = 191 years.
- 12 successive events meets our once in 100 years per tag standard.
- 12 successive events at 4-hour interval also equals 48 hours (2 days) between the first detection of a permanent signal loss and its declaration as valid. The implication is a 2-day delay between “spawning” and pop-up. The delayed pop-up degrades the accuracy of the spawning location, which is assumed to be the Argos pop-up position. In the context of the long migration of eels, and the vast size of the Sargasso Sea, this position uncertainty was considered acceptable.

2.3. Pinger and Tag Configuration

SeaTag-3DS tags and the ATS JSATS pingers are factory configured based on a spreadsheet that you complete and return to DSS. Refer to section 4.1. of the SeaTag-SAM manual for a review of the method. The following parameters are specific to pinger detection for SeaTag-3DS:

- **PD_THOLD:** Defines the sensitivity of the pinger detector. Use the Desert Star recommended value.
- **PD_DWIN, PD_LWIN:** Defines time windows used to identify valid pings and reject random noise. Use the Desert Star recommended values.

- **PD_INT:** Defines the Ping Repeat Interval (PRI) for the JSATS pinger. In most cases 90 seconds is used to maximize the pinger battery endurance. A shorter interval may be used for a test tag or special purposes. Discuss with DSS.
- **PD_APAUSE:** Defines the pause between pinger detection attempts. This is a determining factor of the SeaTag-3DS battery life if no sunlight exposure is available during the tag's time on the fish. See the table below.
- **PD_AFAIL:** The number of successive ping detection fails that will lead to a pinger detection signal loss event and the release of the tag from the fish if enabled. A higher number provides a greater confidence that the pinger has indeed been left behind, but it also delays tag pop-up and therefore provides a less accurate estimate of the spawning location.
- **PDSL_RELEASE:** If YES is selected, SeaTag-3DS releases from the fish to pop-up and report upon detection a pinger signal loss. This is the typical configuration. However, in some cases it may be preferred that the tag remain on the fish for an observation of the post-spawning period. In that case, select NO. The signal loss event packet will still be reported once the tag pops up, although with some risk: If the tag should experience a power loss (depleted battery in darkness), then the event packet will be lost because it is not archived but rather maintained in RAM memory. Further, disabling signal loss release means there will be no pop-up position indicating the spawning location. However, a lesser accuracy position may still be available from the noon time and magnetic field intensity observations from the day of the signal loss, which are reported in the event packet.
- **PD_MODE:** Allows for different pinger signal loss detection strategies. Currently, only mode '1' which is 'Pinger Detection & Pause' is recommended.
- **DN_MODE:** This is not pinger detection related. It is a new optional mode to time the day/night transition, which in the daily summary packet is described as the local apparent noon time and the day length. The local apparent noon time is used to compute the longitude of the tag for a given day (magnetic field intensity is the proxy for latitude). Normally this is done via light intensity measurements using the solar panel. But this only works when the fish is in the euphotic region, with an illuminance of at least 1% of the surface value. Eel stay well below that region, but they have been observed to reliably dive deep in the morning, and return to a shallower depth at night. If you set DN_MODE to '1', day/night detection will be based on depth measurements, while '0' results in light based day/night detection.
- **DN_TH:** If DN_MODE is '1' (depth-based day/night detection), then DN_TH defines the depth that demarcates the day from the night habitat. Deeper than this threshold is considered day, and shallower is considered night. Both the depth and the light based method uses filtering to reject depth or light spikes that may cause erroneous results.

PD_APAUSE	4 min	15 min	30 min	60 min	120 min	240 min
Endurance	0.7 months	2.6 months	5.1 months	9.9 months	18 months	31 months

Figure 9: SeaTag-3DS battery endurance in darkness depending on PD_APAUSE value at a PRI of 90 seconds and when using a sensor sample interval (SRATE) of 4 minutes. Nominal endurance. Applying a 20% safety margin is recommended.

2.4. Pinger and Tag Activation

Prior to fish release, the kinetic release mechanism of SeaTag-3DS must be armed by inserting a powder charge. See section 4.7. of the SeaTag-SAM manual.

Further, SeaTag-3DS is shipped in the 'safe shipping' mode, and must be switched to the On-Fish mode before the fish is released. This is using a simple light sleeve to signal the tag via its solar panel. The method is described in section 5.1. of the SeaTag-SAM manual.

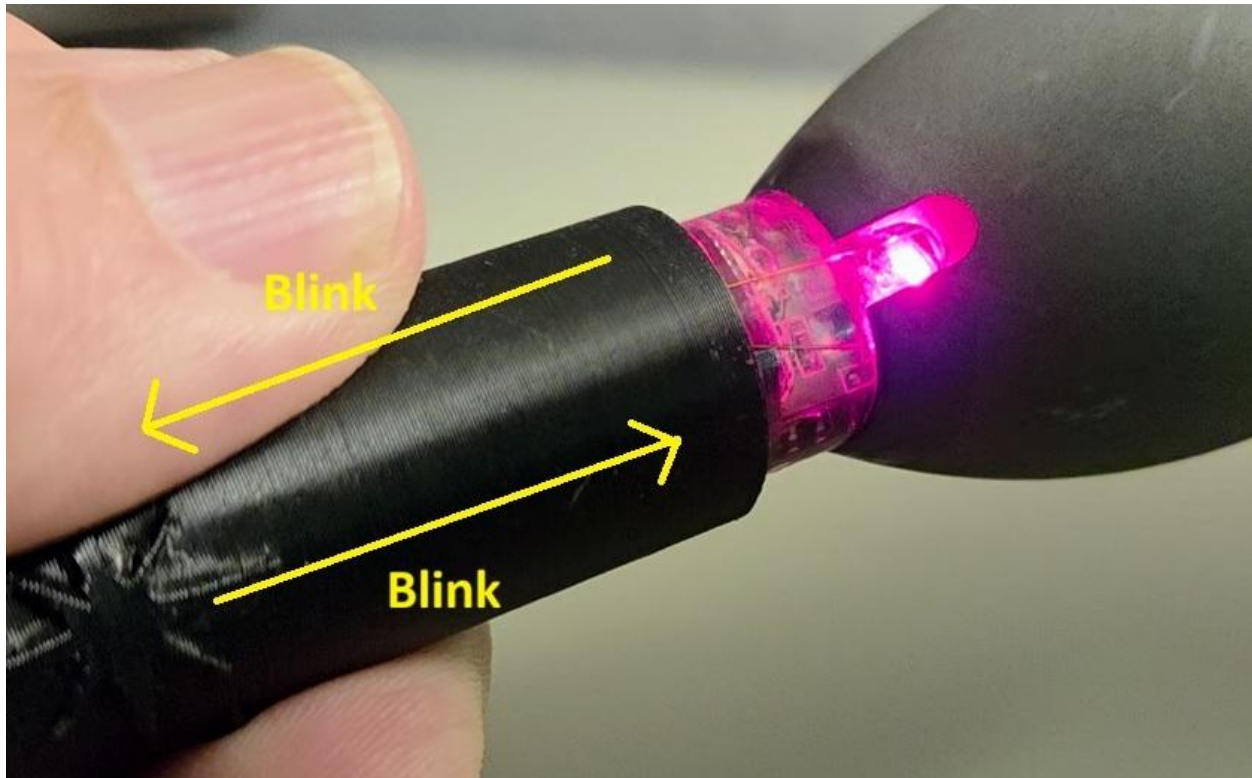


Figure 10: SeaTag-3DS tags are shipped in a 'Safe Shipping Mode' to preserve the battery and prevent any unintended firing of the release mechanism. The tag must then be switched to 'On Fish Mode' for operation. This is done using light signals: Each time the tag blinks, the supplied light sleeve is slid on (dark) or off (light) the solar panel. A long blink announcing the new state (Green = On-Fish, Yellow = Armed, Red = Safe Storage) must be acknowledged by quickly sliding the sleeve on and off until green blinking confirms the new state (or red blinking rejects indicates the old state is maintained). Set aside some training time to learn this; it is easy once you are familiar with the procedure.

The pinger must also be activated. ATS pinger activation requires that you have the Pinger Dish 4 device from ATS. For the longer endurance pingers such as the SS440 model, it may be preferred that DSS activates the pinger before shipping. This starts running down the battery reserves of the pinger. But as long as tagging will happen within a few months, it can be a reasonable strategy that avoids your need for a Pinger Dish and the activation step. Discuss this with DSS.

Finally, you must monitor and confirm that pinger detection works correctly. Once in its On-Fish state, SeaTag-3DS will search for the pinger signal every 4 minutes. This 4-minute interval is fixed and is independent of the PD_APAUSE value. This is so that you don't have to watch the tag for a long time if you are using a long PD_APAUSE period to maximize pinger life. However, at the 4-minute pinger detection interval, the SeaTag-3DS battery will last only about three weeks. So, do the monitoring test within a few hours of switching to On-Fish in order to preserve battery life. You can monitor before or after tagging the fish.

Monitoring before tagging the fish: Switch the tag to On-Fish, and make sure the pinger is activated and at the correct PRI that matches the tag configuration. Place the tag and the pinger in a water filled bucket or similar. Keep the light low so that you can observe the tag LED. The pinger detection process starts once every 4 minutes. It is indicated by a 'long' yellow blink (0.5 second long) that is distinct from the 1/16th second heartbeat blinks of the tag. If the tag detects three pings in a row at the expected interval, first detection has succeeded. This is indicated by the green LED flashing for 30 seconds. If the correct ping sequence has not been detected, there will be a red blink (0.5 seconds), and the process repeats at the next 4-minute interval. You can now implant the pinger and attach the tag to the fish. But be careful: For this method, you must be sure that pinger implantation, tagging and fish release into a holding container is complete in less time than PD_APAUSE * PD_AFAIL. Or else the release mechanism will trigger.



Figure 11: Monitoring first pinger detection before tagging the fish: A JSATS pinger (in blue circle) is activated and a SeaTag-3DS tag is switched to On-Fish state. Both are placed into a water filled container. After SeaTag-3DS detects and verifies the pinger signal, it flashes its LED green (green circle) for thirty seconds to confirm. Care must be taken that the surgical procedure is fast enough and the tagged fish is placed in a holding tank before the tag declares pinger signal loss. Or else the release mechanism will fire!

Monitoring after tagging the fish: Implanting the pinger and attaching the tag before first pinger detection monitoring is an option. The advantage is that you are testing the complete pinger signal path, from inside the fish to the external tag. But it requires transferring the fish to a darkened container suitable for monitoring immediately after the implantation and attachment procedure is completed.



Figure 12: Monitoring pinger detection after implantation and tag harnessing has the advantage that the entire acoustic signal path from inside the fish to the SeaTag-3DS detector is verified. This is a better test! But, it also requires that the fish is monitored immediately. And it must be fairly dark to spot the blinking green LED pattern of the tag reliably.

Alternative: Tag configuration, activation and results inspection using the docking station for SeaTag-3DS (and other SeaTag-SAM tags).

This manual described tag configuration at the factory, and activation using the light sleeve method. An alternative is the use of the SeaTag-SAM docking station. This device lets you configure the tag, obtain special reports such as ping detection statistics, switch the tag between its operating states and install updated firmware. This does require additional knowledge and involves the cost of the docking station and a notebook PC. So, it is a bit of an ‘expert mode’. Contact DSS if you want to learn more or obtain a quote.



Figure 13: For the DTU project, we used on-site configuration of the tags using a specialized tag docking station (center with SeaTag-3DS inserted) and notebook PC. This provides flexibility in the field. But also requires additional knowledge and equipment.

SPAWNING DETECTOR REPORT

Spawning detection parameters:

JSATS PRI: 16.0 +/- 1.600 sec, inter-ping consistency +/- 201 ms

Pause between ping acquisition attempts: 60 sec

Pinger Acquisition & Pause mode

Spawning event declared after 10 successive pinger acquisition fails equaling 12 minutes

JSATS ping detection threshold 10 ADC units (range 0-500 units)

Pinger detector status:

Spawning Event Detected

Max. successive acquisition fails: 4

Acquisitions: 159 total, 103 detections

Max. Amplitude: 1042 all, 1042 detections

Avg. Amplitude: 123 all, 180 detections

Figure 14: Spawning Detector Report. This is one of the tag reports available when using the docking station for SeaTag-3DS. The top portion of this report for the DTU lake test shows the configuration settings, including for example the ping detection threshold at 10 unit. Listed further down is the average signal amplitude for detections at 123 units. So, average signal amplitude is 12.3x the detection threshold. Noise was measured in a separate test as < 1 unit average. Therefore, we have a margin of 12:1 between signal and detection threshold, while maintaining a margin of at least 10:1 between the threshold and observed noise. The large margins should translate to reliable pinger signal detection, allowing for substantial signal fading and excess noise.

2.5. Data Return Monitoring

Following fish release, **you must set up to collect Argos data returns immediately. At most no more than 20 days after the fish is released into the water!** This is done via SeaWatch, a utility that runs in the background on a PC and checks the CLS Argos server for new data once per hour. The limitation is that this machine readable CLS server (CLS web services) provides only the last twenty days' worth of data. If SeaWatch is not running or cannot access the internet for twenty days, you will have a data hole. Data can still be recovered in this case, but it involves a fair amount of manual data sorting and decoding which is best avoided.

SeaWatch creates a .DRL (Desert Star Raw Log) for each tag, which grows as more data becomes available on the CLS server. The .DRL file is decoded using SeaConvert, creating a .zip archive of a set of .csv files that contain the decoded data for each packet type. Other .csv files contain statistical and other meta information. Tracks based on geo measurements are obtained using the SeaTrack software. It uses a .drl file for a tag as its input, and it creates a .kml and a .csv file with track information. The software and method is described in [Chapter 6 of the SeaTag-SAM manual](#).

A fundamental concept of SeaTag-3DS is that it is designed to sense permanent pinger signal loss, not spawning. So, a spawning event is inferred from pinger signal loss. But pinger signal loss can also have other causes. A careful evaluation of data returns is necessary to determine if an indicated signal loss event indeed was caused by fish spawning leading to pinger ejection.

To evaluate this, you must first understand how and what data is remote reported by SeaTag-3DS.

SeaTag-3DS transmits all data in the form of data packets. There are several tag model specific data packet types, which are listed in [chapter 2.3. of the SeaTag-SAM manual](#). The SeaTag-3D packet types apply to SeaTag-3DS. In addition, SeaTag-3DS also transmits a packet that describes a signal loss event and is a central data return element to discern spawning. This is the SDPT_3DPDSL2 packet.

The data packets are divided into three categories:

Packet Category	PacketTypes for SeaTag-3DS	Transmission Scheme
Priority Archival Packets	SDPT_3DDAILY3: Daily observation summary packet (version 3) SDPT_3DHST_DT10: Dynamic Depth & Temperature Histogram with ten bins.	1. Transmitted in a repeated time sequential loop during the initial priority transmission post pop-up (reporting state) phase. 2. Transmitted along with non-priority archival packets in a repeated time sequential loop following the priority transmission post pop-up phase. 3. Transmitted as opportunistic transmissions while still in On-Fish state, that is prior to the release mechanism firing.
Non-Priority Archival Packets	SDPT_3DSN2: All sensor scan & snapshot (version 2)	Transmitted in a repeated time sequential loop following the priority transmission post pop-up phase.
Engineering & Event Packets	SDPT_3DEN2: Engineering packet (version 2) SDPT_3DPDSL2: Pinger detection signal loss (version 2, starting with firmware V4.30)	Transmitted every 10 th transmission. Alternate transmission of the two packet types if PDSL has been registered.

Figure 15: Data packet types and categories for SeaTag-3DS

Here is a description of the Pinger Detection Signal Loss Packet. It is formed when the pinger signal has failed to be detected a continuous number of times as defined by the PD_AFALL configuration parameter. The data fields reflect the sensor reading or state at the time of the first failed pinger detection in the sequence.

Field Description	Field Name	Reporting Units
Packet Name	SDPT_3DPDSL2	n/a
Total count of pinger detection cycles since On-Fish start	PD_COUNT	16-count
Max. continuous pinger detection signal loss sequence prior to final loss sequence	PDSL_RMAX	Pinger detection attempt count
Percentage of pinger detections OK	PD_PCTOK	1%
Local Apparent Noon Time at PDSL	NOON.UTC16	2-seconds
Day Length at PDSL	Daylength16	2-seconds
Pinger Detection Signal Loss (PDSL) Date & Time (Mission Elapsed Seconds)	MES	1-second
Solar panel voltage at PDSL	Vsol8	0.016V
Depth at PDSL	Depth16	0.1 m
Temperature at PDSL	Temp16	0.01 °C
Average Daily Magnetic Field Intensity at PDSL	Mag_MAvg16	10 nT

Figure 16: The Pinger Detection Signal Loss Event Packet (starting with firmware V4.30)

Also important for the evaluation of a registered signal loss event is the tag status byte, SSTAT8. This is transmitted as part of the engineering packet, and also as part of most archival packets. SSTAT8 always reflects the state of the tag at the moment of packet transmission to Argos. NOT the state when an archival packet was recorded. By transmitting the SSTAT8 byte as a part of many packets, the current state of the tag is quickly reported. [Section 2.3 of the SeaTag-SAM manual](#) describes this status byte in detail. Relevant for spawning event evaluation are two general aspects of this byte:

1. The tag mission state at the moment of transmission. In particular **On-Fish** (release mechanism has not yet fired) or **Reporting** (the release mechanism has fired).
2. The release trigger code describing why the release has been fired and Reporting state has been entered. If the reason is a Pinger Detection Signal Loss (PDSL), the code '0' is used which in general terms describes a Special Mission Event (SME). Other codes show that the release has been fired and the tag has popped-up for a different reason, such as the programmed release time has been reached.

2.5.1. Spawning Event Evaluation

Pinger Detection Signal Loss serves as a proxy for spawning. But signal loss can happen for multiple reasons. Here is a list of examples, and surely there are more of them:

- Spawning with pinger ejection
- Tag shedding
- Prolonged pinger signal fading
- Pinger battery dead, pinger failed, detector failed
- Mortality event
- Predation event
- Fishing event

To determine if a signal loss is indeed an indication of spawning, review all available data sources. The table provides examples of what might be observed for different causes of pinger signal loss.

Event	Tag State (SSTAT8)	SDPT_3DPDSL2 sensor readings	PDSL_RMAX Value	Other indicators / comment
Spawning	REPORTING	Depth and temperature consistent with spawning	Small compared to PD_AFAIL value	Fish migration and behavior described in daily summary packets and sensor snapshots is consistent with spawning.
Shedding	First ON-FISH, then REPORTING	Depth and temperature reflect surface conditions	Small compared to PD_AFAIL value	Tag popping up and reporting still in ON-FISH state means that shedding was the reason that the pinger signal was subsequently lost.
Unreliable pinger signal detection (fading)	REPORTING	May or may not be consistent with spawning	Close to the PD_AFAIL value	A large PDSL_RMAX value suggests that pinger signal detection was too unreliable to discern spawning.
Pinger or detector died	REPORTING	May or may not be consistent with spawning	Small compared to PD_AFAIL value	If you kept an active test pinger in the lab, check it now to see if it is still pinging.
Mortality	REPORTING	May or may not be consistent with spawning	Small compared to PD_AFAIL value	Check daily summaries and sensor scan packets. Do they indicate a dying fish?

Predation	REPORTING	May or may not be consistent with spawning	Small compared to PD_AFALL value	Check daily summaries and sensor scan packets. Do they indicate that tag has been ingested?
Fishing	REPORTING	Depth and temperature reflect surface or fish tank / freezer conditions	Small compared to PD_AFALL value	Check daily summaries and sensor scan packets. Do they show unusual conditions that imply the tag was not in the water at the time of signal loss?

Figure 17: A suggested condition table to evaluate tags that report a Pinger Detection Signal Loss (Code-0) event

3. Final Thoughts: What Level of Support Do You Need?



Figure 18: Night release of tagged and pinger implanted eel

Spawning detection is a new concept for PSAT tags, and it provides new research opportunities. Yet, operating a PSAT tag with an acoustic pinger detector adds additional complexities. At the conclusion of the eel tagging project, I asked the DTU team if my support of the work in the Azores was necessary. The unequivocal answer, they could not have done it without my presence.

New technologies invariable present these types of challenges. This manual contains a number of 'lessons learned' that already led to some firmware and

methods changes which are described here. And this manual seeks to make your independent SeaTag-3DS operation more realistic. But the reality is that a community of expert users of this tag does not exist yet. And best practices are only now starting to be defined; this manual being one example of this effort.

Consider what level of support is right or is needed to maximize the probability of success for your study. And contact us about it. It is a critical juncture for this technology, and your DSS team is here to help!