2008/805 | September 2010

Australian Government
Australian Fisheries Management Authority

Testing seabird and turtle mitigation efficacy of the Smart Hook system in tuna long-line fisheries – Phase 1

www.afma.gov.au

Protecting our fishing future

Box 7051, Canberra Business Centre, ACT 2610 Tel **(02) 6272 5029** Fax (02) 6272 5175 **AFMA Direct 1300 723 621**

Testing seabird & turtle mitigation efficacy of the Smart Hook system in Tuna long-line fisheries.

Author: Hans Jusseit

ISBN # 978-0-646-54829-6

Table of Contents

Non Technical Summary *3*
Objectives: 3
Summary 3
Outcomes 3
Research Need 4
Research results 4
Conclusion 5
Further work 5
Acknowledgments *6*
Background *7*
Need *9*
Methods *10*
Component 1 Testing on Seabirds 10
Component 2 Testing on Turtles 12
Component 3 Operational Trial 13
Results/Discussion *14*
Seabirds 14
Turtles 14
Operational Performance 16
Discussion 16
Benefits and adoption *17*
Further Development *17*
Planned outcomes *18*
Outputs 18
Conclusion *18*
References *20*
Appendix 1: *22*
Intellectual Property 22
Appendix 2: *23*
Staff 23
Appendix 3 ..... *24*
Raw Data 24
Attachment 1 *Testing of the 'Smart Hook' Seabird By-catch Mitigation Device*
Attachment 2 *Testing The Bycatch Mitigation Efficacy Of the Smart Hook For Sea Turtles.*
Attachment 3 *Operational Performance of the Smart Hook System in a Commercial Tuna Fishing operation.*

Non Technical Summary

2008-805	**A Pilot study - Testing seabird & turtle mitigation efficacy of the Smart Hook system in tuna long-line fisheries.**

PRINCIPAL INVESTIGATOR: Mr. Hans Jusseit
ADDRESS: AHi Enterprises Pty Ltd
PO Box 1080, Mooloolaba QLD 4557
Telephone: +61 410 499 824 Fax: +61 410 499 824

Objectives:

1. Observe, document and record seabird behavioral responses to the Smart Hook and its effectiveness.
2. Observe, document & record turtle behavioral responses to the Smart Hook and its effectiveness.
3. Determine operational performance of the Smart Hook System in a commercial fishing operation.

Summary

Outcomes

This project provides the necessary information and understanding for fisheries managers and the fishing industry to adopt the Smart Hook system as a method to prevent the capture of seabirds and turtles in long-line fishing.

The Smart Hook system demonstrated its effective ability to eliminate the capture of seabirds and turtles[1] and performed well during the setting of tuna long-lines.
The demonstrated increase in the sink rate of the baited hook can reduce the seabirds' access to the hook, providing confidence in its ability to be used as a mitigation method.

Changes to the design were identified and successfully incorporated before the operational trials were performed.
A notable increase in fish catch using the Smart Hook system, thought to be due to an increase in bait retention, can be an added incentive for fishermen to use the system.

Discussions with fisheries mangers and industry operators were positive and supportive, indicating a willingness to use the system.

Implementation of the Smart Hook system will provide an additional environmental safe guard in the conservation of sea birds by reducing the mortalities due to the impacts of fishing.

Large-scale use of the Smart Hook system can provide a new manufacturing industry, employment and exports for Australia.

[1] Due to a lack of turtle aggregations captive turtles were used during the project experiments.

Research Need

The indiscriminate deaths of seabirds & turtles in long-line fishing and the failure to solve this problem has resulted in fisheries closures, restrictions, operational and productivity impacts increasing the need to find a solution to the problem.

The tuna fishing industry needs a seabird & turtle mitigation system that is proven to be simple, cost effective, and commercially available.

National plans of action and legislation require fishing to reduce and minimize impacts on threatened, endangered and protected species.

New mitigation measures have required scientific testing, to show effectiveness, before implementation by agencies or acceptance by fishing industries.

Development of the Smart Hook System needs to be tested biologically, in the commercial fishing & marine environment using scientific methods to provide creditable evidence of its effectiveness to stakeholders.

Research results

Testing of the Smart Hooks system was developed to determine its effectiveness as a preventative measure in the capture of seabirds & turtles and its operational performance in long-line fishing. The results showed that it was effective in preventing the capture of both seabirds and turtles that had direct access to the baited hook. This was achieved by presenting the baited Smart Hook to both seabirds and turtles and observing the interactions.

The project trials[2] showed Seabirds including the Albatross and Giant Petrels were unable to access, ingest or become hooked on the baited Smart Hook. Observations on captive turtles showed they were unable to ingest or become hooked on the baited Smart Hook.

The trials provided, an as yet unobserved, understanding of how turtles become caught by their flippers on long-lines. The turtles were observed attempting to break off pieces of the bait held in their mouth using their flippers in a sweeping outward motion, catching on the hook holding the bait.

The results obtained from the sea trials[3] showed it performed well and was easily incorporated in a commercial tuna long-line fishing operation, possibly with additional benefits. The catch data, though limited, showing the additional catch rate using the Smart Hook system can provide an additional incentive for fishermen to use the system.

---

[2] Attachment 1 Testing of the ‘Smart Hook’ Seabird Bycatch Mitigation Device — Phase 1, Latitude 42 Environmental Consultants Pty Ltd Barry Baker, May 2009
Attachment 2 Testing The Bycatch Mitigation Efficacy Of The *Smart Hook* for SeaTurtles, Dr Kerstin Frtiches 31 March 2008

[3] Attachment 3 Operational Performance of the Smart Hook System in a Commercial Tuna Fishing operation. Hans Jusseit August 2010

Conclusion

This project shows conclusively the Smart Hook system is a positive measure to prevent the ongoing environmental impact the tuna long-line method has on seabird and turtle populations.

The positive results of these trials suggest actions should be taken to implement the system as part of a mitigation strategy.

The testing conducted in the trials[4] successfully demonstrated the Smart Hook could not be accessed by seabirds or ingested by sea turtles. The trial results show the Smart Hook did not catch any seabirds or turtles, it has now been proven to be an effective method to prevent the capture of seabirds & turtles whilst setting Tuna long-lines.

The results of the project show the smart hook system did not directly or indirectly catch seabirds or turtles that were directly exposed to it and performed well under commercial operational conditions.

It is a solution that can be implemented into fisheries management and tuna long-line operations, quickly reducing the impact of long-line fishing on endangered seabird and turtle populations.

Further work

The collection and analysis of more data from vessels using the Smart Hook system in tuna long-line fishing operations can provide further assessment of its effectiveness and benefits.

The system can be further developed to be used in demersal and Autoline fishing systems.

There can be additional research into the production process to reduce the production costs e.g. Production line development and the use of recycled materials.

KEYWORDS:

Seabirds, Turtles, Long-line, Smart Hook, Tuna, Mitigation, Manufacturing.

[4] Attachment 1 Testing of the 'Smart Hook' Seabird Bycatch Mitigation Device — Phase 1, Latitude 42 Environmental Consultants Pty Ltd Barry Baker, May 2009

[4] Attachment 2 Testing The Bycatch Mitigation Efficacy Of The *Smart Hook* for SeaTurtles, Dr Kerstin Frtiches 31 March 2008

Acknowledgments

The author wishes to acknowledge and thank all those involved in this project for the dedication, support, patience and contributions. Many groups and individuals provided in kind support and assistance and advice, with confidence, believing that the Smart Hook system has great potential in reducing the impact of long-line fishing on seabirds & turtles.

Financial support and funding was received from the Australian Fisheries Management Authority in conjunction with Fisheries Research and Development Corporation to conduct this project. The Department of Innovation and Technologies COMET program provided the initial funding to progress the development of the Smart Hook system.

Special thanks to Barry Baker for his dedication to the work, his help, advice and assistance in showing the Smart Hook is a real solution.

Special thanks also to Dr Kerstin Fritches for her experience, dedication, scientific understanding and suggestions to prove the effectiveness of the Smart Hook system on turtles.

I add my special thanks to those acknowledged in the separate reports contained herein, including Dennis Burrman, Kaikoura Encounter, Ben Higgins from the National Marine Fisheries Service (NMFS) Sea Turtle Facility in Galveston, Texas USA and the team from Underwaterworld on the Sunshine Coast, Queensland Australia. Their assistance and support were paramount in cost effectively conducting the experiments.

Special thanks to Bob Lamason of Great Barrier Reef Tuna, his FV Rummage its Captain and crew. Bob’s ongoing in kind contributions and commitment to the tuna fisheries science and understanding is an inspiration.

Thanks also to the manufacturers and designers who spent countless more hours than they were paid for helping to modify the design, develop tooling and produce the Smart Hook system components.

Finally infinite thanks to Jim Uttleymoore as business partner and Alistair and Gabrielle Mackellar as shareholders in AHi Enterprises Pty Ltd. They must be acknowledged for their financial and mentoring support to me, the company and the conservation need during the development and testing.

Background

The pilot study was undertaken to determine the effectiveness of the smart hook system in long-line fisheries prior to implementing the Smart Hook system on a larger scale.

The incidental catch of seabirds & turtles by long-lines is a key threatening process to the survival of both groups of marine life. The impact of this issue on the ecosystem, biodiversity and all costs associated with fisheries restrictions and or closures, associated with addressing this problem, is difficult to measure.

To date no single, simple solution has been developed to mitigate seabird and turtle by-catch for the pelagic long-line method, which is used throughout the world to target tunas and swordfish.

The Smart Hook System is a new innovation designed and developed to revolutionize the mitigation of seabird and turtle interactions in long-line fishing, by the prevention of hooking during the Long-line setting process in a simple, costs effective manner.

The Smart Hook System has been developed to mitigate the seabird & turtle interaction of long-line fishing in the marine environment in one system using several distinct methods at once: hooking prevention, interaction deterrence, avoidance & minimization.

The Smart Hook functions like no other mitigation measure by a patented system that allows a barrier to be attached to the hook, preventing the hooking of seabirds & turtles during setting of long lines. The non-polluting, degradable barrier detaches from the hook after a short period of time, using technology, allowing fish to be caught after the baited hook has passed beyond the feeding depths of seabirds & turtles.

There are specific benefits of the Smart Hook including;

Environmental

- Positively prevents hooking of seabirds & turtles during setting
- Positively prevents ingestion during setting
- Non-polluting, degradable material (complies with MARPOL)
- Reduction of Lead in the environment by reducing the need to use lead swivels in the fishing gear
- Possible reduction of other by-catch.

Fishing

- Increases flexibility of fishing
- Reduces or eliminates the need for multiple mitigation methods e.g. Tori Lines leading to MCS cost savings
- Increases sink rate at the hook reducing the need for lead swivels
- Indicative cost effective, lost cost solution
- Increase economic returns to fishermen by allowing access to fishing grounds that are restricted or closed e.g. Night time setting, area closures like those imposed in other countries to avoid seabird or turtle interactions,
- Increasing catch rates by additional bait retention
- Simple to use
- Increased safe working practices

Management

- Monitoring, compliance & surveillance applications e.g. the system will be able to monitor effort and use, may provide reductions in aerial surveillance to monitor use of tori lines etc.

- Multi layer IP for protection & QC
- Easy integration into fisheries

The Smart Hook may be able to be developed, in the future, for the demersal long-line fishery to mitigate seabird by-catch in other fisheries.

This project was undertaken to scientifically test the Smart Hook to ensure it is effective, prevents seabird & turtle capture, in an environment that will minimize animal mortalities, prior to any further investment or introduction into long-line fisheries.

It was conducted by consulting, seeking advice and collaborating with experienced scientists, government and industry associates and environmental stakeholders as well as using the applicants experience and knowledge of the tuna fishing industry on a domestic and global level.

The scientific testing and implementation of the Smart Hook System will provide a mitigation system that will help to address animal conservation issues relating to seabirds and turtles.

This Smart Hook system may, in time, be used as or as part of an environmental management system and will assist with future routine environmental certification.

Positive scientific test results and subsequent implementation of the Smart Hook System may assist with meeting regulatory requirements of the EPBC Act and improve environmental management performance for the fishery.

Discussions with scientists and industry lead to some further development to reduce the cost to fishermen and enhance the efficacy of the system. They were as follows;

1. Modify the design to remove the need for an applicator to be used in the system. This was undertaken to reduce the capital costs to fishermen using the system. The shield attachment was redesigned to allow manual application by hand.
2. Modification of the Smart Hook design is to reduce the gap between the hook shank and the shield to prevent entanglement in the device[5]. This was completed by designing the shield to have a deeper keel to receive the hook and changing the position of the modification on the hook.

[5] Page 10, Testing The Bycatch Mitigation Efficacy Of The *Smart Hook* For Sea Turtles, Dr. Kerstin Fritsches 31/3/08

Need

Stakeholders constantly pressure the industry and government to prevent the indiscriminate deaths of seabirds & turtles in long-line fishing. Failure to solve this problem has resulted in fisheries closures , restrictions, operational and productivity impacts.

The tuna fishing industry still needs a seabird & turtle mitigation system that is proven to be simple, cost effective, and commercially available.

National plans of action and legislation require fishing to reduce and minimize impacts on threatened, endangered and protected species.

Historically new mitigation measures have required scientific testing, to show effectiveness, before implementation by agencies or acceptance by fishing industries.

Successful Smart Hook technology and working prototypes have progressed the Smart Hook System to a point where it needs to be tested biologically, in the commercial fishing & marine environment using scientific methods to provide creditable evidence of its effectiveness to stakeholders.

This project seeks to address some of the research priority needs of the ET&BF fishery including;

Research Priority 4

Assessment of the impact and/or reliance of the ETBF on the related pelagic ecosystem, including;

- *development and evaluation of mitigation measures to reduce impacts, such as spatial closures and gear modifications and/or restrictions.*

The following specific project has also been identified as having a High Priority for the delivery of key management information needs over the next 1-3 years in the ET&BF fishery.

Development and evaluation of by-catch mitigation and discard minimization measures in the ETBF.

Objectives

The three objectives to the project were each performed and reported as separate trials.

1. **Observe, document and record seabird behavioral responses to the Smart Hook and its effectiveness.**

Seabird behavioral responses to the Smart Hook system were observed and documented in the field at Kaikoura in NewZealand by Barry Baker and a report[6] produced.

2. **Observe, document & record turtle behavioral responses to the Smart Hook and its effectiveness.**

Seaturtle behavioral responses to the Smart Hook system were observed and documented at the Underwater World Aquarium in Queensland and the National Marine Fisheries Service (NMFS) Sea Turtle Facility in Galveston, Texas, USA. A Report[7] was provided by Dr Kerstin Fritches from University of Queensland.

3. **Determine operational performance of the Smart Hook System in a commercial fishing operation.**

The operational performance testing was conducted in sea trials aboard the FV Rummage, in the Coral Sea. Observations, data and a report[8] was provided by Hans Jusseit from AHi Enterprises Pty Ltd.

Methods

The research examined the mitigation capability of the newly developed Smart Hook system on seabirds & turtles as well as its operational performance. Large Seabird aggregations were used in the wild. Due to a lack of aggregating turtles, captive wild turtles were used in the experiments. The Smart Hook system was then put into a fishing operation. The research work has three components each relating to an objective. Full reports of the experiments in attachments 1-3.

Components 1-3 was undertaken in order to ensure the system is fully functional before it is exposed to a variable environment and to minimize any risk of wild captures.

Component 1 Testing on Seabirds

This component was conduced to address objective 1 in the project.

The Smart Hook was deployed from a vessel in a situation where birds are known to congregate to a vessel to confirm that seabirds are unable to immediately gain access to hooks protected by the Smart Hook shield.

Field work to test the efficacy of the 'Smart Hook' System was carried out off the coast of

[6] Attachment 1 Testing of the 'Smart Hook' Seabird Bycatch Mitigation Device — Phase 1, Latitude 42 Environmental Consultants Pty Ltd Barry Baker, May 2009

[7] Attachment 2 Testing The Bycatch Mitigation Efficacy Of The *Smart Hook* for SeaTurtles, Dr Kerstin Frtiches 31 March 2008

[8] Attachment 3 Operational Performance of the Smart Hook System in a Commercial Tuna Fishing operation. Hans Jusseit August 2010

Kaikoura, South Island, New Zealand. Kaikoura is a well-known seabird ‘hotspot’ that is readily accessible for both seabird observation and research work. It is an area that is routinely frequented by a number of albatross and petrel species that are known to freely interact with commercial fisheries.

We tested the ‘Smart Hook’ System in a series of trials where we placed baited Smart Hooks near individual seabirds that were feeding on the water adjacent to the vessel. Squid and fish baits were presented only to species that were known to freely interact with longline gear, with the species grouped into three categories:

1. large albatrosses (*Diomedea* spp.);

2. smaller albatrosses (*Thalassarche* spp.); and

3. giant petrels (*Macronectes* spp.).

Although we were also intending to test the Smart Hook against White-chinned and other *Procellaria* spp. petrels, and larger *Puffinus* shearwaters, there were none of these species present to permit this.

We approached seabirds in two ways. Birds were either attracted to the boat by chumming, or the boat was positioned adjacent to shark fishing vessels that were hauling nets and processing fish. The resultant discarding of offal by the fishing vessels, or attraction of the ‘chum’ ensured at least 100 birds were in the area at all times during the trial. We then threw baited hooks toward and within 5m of individual birds that were actively feeding near the boat and categorised response variables as:

0. no response

1. bird moves toward Smart Hook, then shows no further interest;

2. bird touches Smart Hook/bait;

3. bird attempts to eat bait but does not swallow Smart Hook;

4. bird ingests Smart Hook and bait, regurgitates gear; and

5. bird ingests Smart Hook and bait, retains gear.

We presented both squid and fish bait types to at least 20 individuals of each of the three seabird categories, to provide a minimum of 120 observations on which to evaluate the response of seabirds to the smart hook.

The feeding birds were approached by either attracting them to the vessel or positioning the vessel adjacent to another vessel the birds were attracted to.

For the animal’ safety both hook tip and barb was be blunted for the unlikely event that the Smart Hook device dislodges from the hook during the experiment.

The opportunity to test the sink rate was taken, performed by using a modified bottle test. i.e. Smart Hook gear was attached to one end of a 12 m length of 2 mm monofilament line, and the other end of the line securely attached to the neck of an empty 1000 ml plastic bottle. The bottle was then attached to a length of twine. The bottle and the attached smart hook gear was then deployed in the water. The bottle lay flat on the water till the smart hook reached 12 m depth and the line under tension pulled the bottle upright. The time at which the bottle entered the water was recorded as well as the time at which the bottle was observed to be pulled upright.

Component 2 Testing on Turtles

This component was conduced to address objective 2 in the project.

Two species of marine turtles were tested, the green turtle *Chelonia mydas* and the loggerhead sea turtle *Caretta caretta*. Information on all animals was tabulated.

Green turtles were accessed at UnderwaterWorld, Mooloolaba, Queensland. Loggerhead sea turtles were tested at the National Marine Fisheries Service (NMFS) Sea Turtle Facility in Galveston, Texas, USA. Both species of turtles were tested in a holding bays.

The Smart Hook shield was the same for all configurations and consisted of a soft steel custom shaped cap-like shield, 64mm in diameter and 1.3mm thick, weighing between 34 and 40g. The hook tips were blunted and barbs flattened to minimise risk of injury to the sea turtles during the trials.

Hook types used:

1. US Circle Hook; size Mustad 16/0
2. Japanese Circle Hook; size 4
3. Japanese Longline Hook; size 3.6

Bait Types:

1. Squid bait
2. Fish (sardines and yellowtail for green turtles, Spanish sardines for loggerhead sea turtles)

Both squid and fish baits were tested, however emphasis was placed on using squid bait, as both the captive green and loggerhead sea turtles were known to prefer squid to fish as food.

Each hook and bait configuration was presented to the animal in mid-water for 5min and the response recorded with a video camera. Interactions were scored based on the video recording (at UnderwaterWorld) and in real-time (NMFS Facility) with respect to whether the animal bit the bait, the shield or the hook, and whether the front flippers were used to interact with the Smart Hook. A single interaction was defined as the timeframe the animal's mouth was in direct physical contact with the Smart Hook or the bait attached.

Testing the interactions with the Smart Hook at natural sink rate was also conducted as follows:

Pacing out the length of the "racetrack" the Smart Hook's natural sink rate of 0.6m /sec (see results Component 1 by B. Baker) was simulated in the horizontal dimension. Also, a much faster sink rate of 1m / sec was tested with 2 turtles. The Smart Hook, using the US circle hook and squid bait, was trailed in the centre of the "racetrack" in mid-water and the loggerhead turtles' response either filmed with a hand-held video camera or recorded on paper in real time. Due to lack of sufficient aquarium space this experiment could not be undertaken with the green turtles.

Post-mortem throat dimensions for green turtles were kindly provided by Dr. Kathy Townsend. These were measured on deceased stranded turtles that had been frozen and then thawed for examination. Calipers were used to measure the narrowest dorso-ventral and left-right diameter in the animal's throat. Staff at Underwater World provided measurements of external gape height at the front of the mouth in living green turtles using a dog gag and digital calipers. Measurements on oral anatomy of living loggerhead turtles were kindly provided by Dr. Lesley Stokes using the animals at the NMFS facility during 2003-2004(Ref).

The experiment is designed as a qualitative assessment of the sea turtle' response to and possible interactions (e.g. biting) with the Smart Hook and will be repeated with several (4-6) animals of two species, the green turtle (Chelonia mydas) and the loggerhead (Caretta caretta).

The experiments were undertaken by Dr Kerstin Fritsches with the inventor of the Smart Hook, Mr. Hans Jusseit, present for some of the experiments. Dr. Fritsches has 12 years experience with aquatic animal research and has been working on sea turtle behavior and sensory capabilities since 2002. Staff and veterinarians of will be available on stand-by during the experiments.

The Smart Hook was deployed under supervision at the Sunshine Coast "Underwater World" aquarium. The Smart Hook was also deployed at the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service's (NMFS) Turtle Research Laboratory in Galveston Texas, to confirm that turtles are unable to immediately gain access to hooks protected by the Smart Hook shield.

The sinking motion of the baited Smart Hook was also observed to ascertain any perceived likelihood of line twisting.

Direct observation and post-experimental analysis of the video recordings was used to describe the interactions and pin-point potential issues for turtle-Smart Hook interactions before the system is tested in field trials in the open water.

For the animal' safety both hook tip and barb were blunted for the unlikely event that the Smart Hook device dislodges from the hook during the experiment.

Component 3 Operational Trial

This component was conduced to address objective 3 in the project.

During the experiments for objective 2, a need to modify the design of the shield was identified. During this time, discussions with fisheries managers and fishermen revealed the system and any potential uptake could benefit by redesigning the shield to avoid the need for specific application equipment.

AFMA was informed of the potential to improve the system and approved the design upgrade before undertaking this component. The shield attachment mechanism was redesigned to allow fishermen to apply it manually without the aid of any special equipment.

It should be noted that the additional redesign and need to work with manufacturers was costly and resulted in the project completion being delayed. However the result is a system that can be more widely adopted.

The Smart Hook was deployed from a vessel in a situation where there is little or no known interaction with seabirds, in far north Queensland in the Coral Sea, to confirm that the system functions under normal operational conditions. The deployment was recorded by video.

All seven settings and hauling operations were observed and noted during the fishing trip.

Branch-lines with the Smart Hook attached were introduced randomly after the first set using one and two sardines per hook as well as squid for bait.

The Smart Hook shield was only attached during fishing conducted in daylight hours.

Video and still photographic media was used to record setting operations.

Catch and effort data was collected and tabled during each set, recording the effort and catch and noting the conditions.

The captain and crew were interviewed on video to document their assessment of the Smart Hook system in the fishing operation.

Data analysis was undertaken to determine any variation in catch per unit effort (cpue).

Results/Discussion

Seabirds

[9]The performance of the Smart Hook was impressive in the presence of abundant and actively feeding seabirds. When deployed the baited hooks sank so quickly the opinion was formed that many birds were barely aware that the baited hooks represented a food source.

The test protocol was to place baited smart hooks within 5 m. of foraging seabirds, but it was only when baits landed within a metre of birds that they displayed any real interest, and attempted to approach (Category 1 or 2) or attack (Category 3) a baited hook. Only six of the 136 birds presented with the smart hook managed to grasp a bait and attempted to feed upon it, but when this happened baits were not retained for long. In all cases squid baits were involved and birds appeared to break a piece off the squid and let the remainder go, at which stage it sank. The action of the birds attacking the bait did not dislodge the Smart Hook barrier and thus expose the birds to the risk of becoming hooked.

The mean sink rate of the Smart Hook (0.54 m/sec) greatly exceeded that observed in unpublished sink rate experiments carried out using dead and live bait attached to hooks and branch-lines with 60 g leaded swivels placed between 2 and 4 m from the hook (G.Robertson unpublished data).

Turtles

[10]The behavioral trials of captive turtles have shown that the Smart Hook successfully prevents both green and loggerhead turtles from being hooked while interacting with the baited or unbaited device.

None of the animals tested were able to remove or destroy the shield despite frequent biting. Most animals showed curiosity and mouthed the device, however in all cases the animal's

[9] Testing of the 'Smart Hook' Seabird Bycatch Mitigation Device — Phase 1, Latitude 42 Environmental Consultants Pty Ltd Barry Baker, May 2009

[10] Testing The Bycatch Mitigation Efficacy Of The *Smart Hook* For Sea Turtles, Dr. Kerstin Fritsches 31/3/08

initial aim was to remove and eat the bait from the device, which they were able to do without contact with the hook tip due to the shield. It was also noted that both green and loggerhead sea turtles actively use their front flippers to help remove bait from the hook, risking foul-hooking in the flippers or the soft flesh of the neck or base of the flipper.

The Smart Hook prevented such foul-hooking in all cases.

While potential preferences for bait types and hook types were detected here, the highly variable behavior of individual animals and the artificial presentation of the device to the captive turtles suggest caution in interpreting these preferences for turtle behavior in the field.

The aim of this study was to test whether there was any difference in the effectiveness of the Smart Hook when using different hook and bait types, the Smart Hook was found to be effective in preventing hooking in all configurations tested.

The size of the shield in the Smart Hook restricts the potential for swallowing to animals of larger carapace size exceeding 70cm for loggerhead sea turtles and close to 100cm for green turtles.

The large majority of loggerhead sea turtles interacting with longline gear appear to be below 70 cm (Bjorndale et al., 2003; Watson et al.2005) suggesting they would be too small to swallow the device. I note, however, that
these size estimates were derived from oral anatomy measurements not accounting for active swallowing in the behaving turtle, which might allow somewhat smaller turtles to swallow the device. In the behavioral trials, none of the turtles tested tried to swallow the device (max. carapace length 56cm).

Ingestion of the hook is a major danger and strongly linked to mortality in sea turtle bycatch; and incidences of ingestion are reduced with increasing hook size (Bolten, 2003; Watson, 2005). Due to the size of the shield, which remains constant regardless of the hook size used, the Smart Hook is likely to reduce the number of incidences of ingestion during the deployment phase, especially compared to using smaller, unguarded hooks.

During the trials it became obvious that a modification of the Smart Hook design is necessary to reduce the angle between the hook shank and the shield to prevent entanglement in the device. This modification can be easily achieved by moving the position of the extrusion that hold the hook in position within the shield and such modification should be undertaken to enhance the effectiveness of the Smart Hook. (Annotation: Modification has now been undertaken accordingly)

The results obtained from the captive sea turtles outlined above demonstrate that the Smart Hook is a highly effective device to prevent hooking of the mouth and other body parts, of green and loggerhead sea turtles.

Operational Performance

[11]The Smart Hook system appears to be easily incorporated into the Tuna long-line fishing operations.

The Smart Hook system performed well under all conditions experienced as well as some not expected e.g. soaking by a breaking wave.

The Smart hook system can be easily included into Tuna long-line operations to mitigate the capture of seabirds and turtles.

Analysis of the data shows the Smart hook system increased the CPUE, increasing productivity and economic return.
The indication of an increase in the CPUE, whilst derived from a small data set, warrants the Smart Hooks use on a larger scale. The increase in CPUE is believed to be due to

1. An increase in bait retention, resulting in fish having access to more baited hooks,
2. The bait reaching the target species quickly, whilst
3. Avoiding non-target species due to the increased sink rate.

Discussion

Seabirds and turtles responses to the Smart Hook whilst feeding indicated it was effective in preventing the capture of both seabirds & turtles in several ways.

The Smart Hook system performed well during fishing operations, indicating there are no obstacles to using the Smart Hook system in tuna long-line fisheries where there is a need to mitigate seabird and turtle by-catch and that it can be an asset to the operations.

The operational performance data, whilst small, indicated an increase in the catch of fish. This can provide and economic return and incentive that may offset the cost of the Smart Hook system.

The cost of the system will determine the uptake, rate of environmental and economic benefit. This can be overcome with a large number of Smart Hooks being deployed to reduce the cost of using the system. Once a large volume of the shields are being produced the costs will make the system very economical to use.

[11] Operational Performance of the Smart Hook System in a Commercial Tuna Fishing operation. Hans Jusseit,August 2010

Benefits and adoption

The global and domestic Tuna long-line industry will benefit from the implementation of the Smart Hook system into their fishing operations. The overall benefits will be determined by the cost of using the system. This cost can minimized by mass production of the Smart Hook shield. E.g. the cost of the shield to fishermen can be as high as ~US$0.50 (50cents) per shield if initial production is for less than one million units. This cost can be reduced to ~US$0.20 (20cents) for greater than 10 million units. There fore once the system is implemented on an ongoing basis the reduced cost can be maintained.

Some of the benefits the fishing industry can have include;

- Productivity increases by additional bait retained on the hook whilst setting, increasing the CPUE by up to 10%.
- Access to restricted areas or the lifting of closures. This provides access to highly productive areas, reducing fishing time and costs .
- Tuna long-line fishing can be seen as an environmentally friendly form of fishing, providing greater returns on fish prices through the consumer choice programs.

Government agencies will be able to benefit by the implementing this system to achieve their statutory requirements, enabling them to focus resources on other fisheries and environmental issues.

Conservation groups will benefit by supporting the use of the Smart Hook system as a solution providing them with an opportunity to focus their resources on other environmental issues that may require more resources.

The scientific community, in particular seabird scientists, will be able to benefit with the ongoing research required to monitor changes in bird populations.

Further Development

The following recommendations are suggested:

1. The Smart Hook system be implemented into Tuna Long-line fisheries management at all levels.
2. The Australian government move to have the system recognized and adopted at international fisheries management levels including and in particular the regional fisheries and conservation management organizations. E.g. WCPFC, CCSBT, CMALAR, ACAP, IATTC, etc.

The results of this research can be a precursor to additional research and development in the following areas;

1. Modify the system to enable it to be used in demersal and auto long-line fishing operations.
2. Implement the Smart hook system into a fishery.
3. Collect and analyse additional catch and effort data where the Smart Hook is used, to;
    a. Provide further environmental assessment as a mitigation method on both seabirds and turtles individually,
    b. Undertake an economic benefits assessment of the Smart Hook use in fishing operations.

4. Research production cost savings by;
    a. Use of recycled materials
    b. Production line development
5. Develop an identification system e.g. serial or bar coding, to be used with the Smart Hook system to assist with data collection to assist in further research as well as MCS programs.

Planned outcomes

Outputs

The dissemination of the scientific data, information and knowledge from this report will enable decision makers including fisheries managers and fishermen, to implement the Smart hook system on a large scale in a commercial fishing operation. In simple form, the report provides clear evidence that the Smart hook does not adversely affect the behavior of seabirds or turtles, showing that they do not get hooked when the system is deployed.

The report will act to reduce the need for further invest in the development of a new system.

The information will be used to support larger scale use of the system. Some of the non commercial outcomes have already been documented and disseminated via the internet www.smarthook.biz .

Information gained from the experiments will be used to encourage uptake of the system in tuna long-line fisheries.

Information from the reports may also be used to improve the system.

The project report will provide manufactures, who are reluctant to invest in production, with confidence that the system is sound and has potential market uptake.

Conclusion

This project shows conclusively that ways should be found to implement the Smart Hook system into tuna long-line operations as soon as possible to prevent the ongoing environmental impact the method has on seabird and turtle populations.

The three objectives to the project were each performed and reported as separate trials. All objectives were completed as follows;

Seabird behavioral responses to the Smart Hook system were observed and documented in the field at Kaikoura in NewZealand and a report[12] produced.

Seaturtle behavioral responses to the Smart Hook system were observed and documented at the Underwater World Aquarium in Queensland and the National Marine Fisheries Service (NMFS) Sea Turtle Facility in Galveston, Texas, USA and a Report[13] was provided.

The operational performance testing was conducted in sea trials aboard the FV Rummage, in the Coral Sea. Observations, data and a report[14] was provided.

---

[12] Attachment 1 Testing of the 'Smart Hook' Seabird Bycatch Mitigation Device — Phase 1, Latitude 42 Environmental Consultants Pty Ltd Barry Baker, May 2009

[13] Attachment 2 Testing The Bycatch Mitigation Efficacy Of The *Smart Hook* for SeaTurtles, Dr Kerstin Frtiches 31 March 2008

[14] Attachment 3 Operational Performance of the Smart Hook System in a Commercial Tuna Fishing operation. Hans Jusseit August 2010

The Smart Hook system has been proven to be an effective method to prevent the capture of seabirds & turtles whilst setting Tuna long-lines.

It is a solution that can be implemented into fisheries management and tuna long-line operations, quickly reducing the impact of long-line fishing on endangered seabird and turtle populations.

The performance of the Smart Hook was impressive in the presence of abundant and actively feeding seabirds. When deployed the baited hooks sank so quickly the opinion was formed that many birds were barely aware that the baited hooks represented a food source.

The Smart Hook successfully prevents both green and loggerhead turtles from getting hooked while interacting with the baited or unbaited device.

The Smart Hook prevented foul-hooking in all cases and was found to be effective in preventing hooking in all configurations tested. The Smart Hook is a highly effective device to prevent hooking of the mouth and other body parts, of green and loggerhead sea turtles.

The Smart Hook system can be easily incorporated into the Tuna long-line fishing operations and performs well under all operational conditions so far experienced including wet weather.

The Smart hook system increased the CPUE, increasing productivity and economic return. This indication of an increase in the CPUE, whilst derived from a small data set, warrants the Smart Hooks use on a larger scale.

The dissemination of the scientific data, information and knowledge from this report will enable decision makers including fisheries managers and fishermen, to implement the Smart hook system on a large scale in a commercial fishing operation.

In simple form, the reports provide clear evidence that the Smart hook does not adversely affect the behavior of seabirds or turtles, showing that they do not get hooked when the system is deployed and is easily used and incorporated into fishing operations.

The results of the reports reduce the need for further investment in the development of a new system.

The information can be used to support larger scale use of the Smart Hook system.

References

Testing of the ‘Smart Hook’ Seabird Bycatch Mitigation Device — Phase 1, Latitude 42 Environmental Consultants Pty Ltd Barry Baker, May 2009

Testing The Bycatch Mitigation Efficacy Of The *Smart Hook* for SeaTurtles, Dr Kerstin Frtiches 31 March 2008

Operational Performance of the Smart Hook System in a Commercial Tuna Fishing operation. Hans Jusseit August 2010

ACAP Seabird Bycatch Working Group. 2007. Report of the first meeting of the Seabird Bycatch Working Group of the Agreement on the Conservation of Albatrosses and Petrels, Valdivia, Chile, 17-18 June 2007. ACAP AC3 Doc.14 Rev 5.

Alexander, K., Robertson, G. and Gales, R. 1997. *The incidental mortality of albatrosses in longline fisheries.* Australian Antarctic Division, Tasmania. 44 pp.

Baker, G. B., Gales, R., Hamilton, S. and Wilkinson, V. 2002. Albatrosses and petrels in Australia: a review of their conservation and management. Emu 102, 71–97.

Baker, G.B. and Wise, B.S., 2005. The impact of pelagic longline fishing on the flesh-footed shearwater Puffinus carneipes in Eastern Australia. Biological Conservation 126, 306–316.

BirdLife International 1995. *Global Impacts of Fisheries on Seabirds.* A paper prepared by Birdlife International for the London Workshop on Environmental Science, Comprehensiveness and Consistency in Global Decisions on Ocean Issues. 30 November – 2 December 1995.

BirdLife International, 2004a. Threatened birds of the World 2004. CD-ROM. Cambridge, UK, BirdLife International

BirdLife International. 2004b. Tracking ocean wanderers: the global distribution of albatrosses and petrels. Results from the Global Procellariiform Tracking Workshop, 1–5 September, 2003, Gordon’s Bay, South Africa. Cambridge, UK; BirdLife International; 2004.

CCAMLR. 2007. Schedule for conservation measures in force, 2006–2007. Commission for the Conservation of Antarctic Marine Living Resources, Hobart.

Croxall, J.P. 1998. Research and Conservation: a future for albatrosses? Pp. 269–290 in *Albatross: Biology and Conservation*. Robertson, G. and Gales, R. (eds.). Surrey Beatty and Sons, Chipping Norton.

Croxall, J.P. and Gales, R.P. 1998. An assessment of the conservation status of albatrosses. Pp. 46–65 in *Albatross: Biology and Conservation*. Robertson, G. and Gales, R. (eds.). Surrey Beatty and Sons, Chipping Norton.

Gales, R. 1998. Albatross populations: status and threats. Pp. 20–45 in *Albatross: Biology and Conservation*. Robertson, G. and Gales, R. (eds.). Surrey Beatty and Sons, Chipping Norton.

Melvin, E. F., Sullivan, B., Robertson, G. and B. Wienecke. 2004. A review of the effectiveness of streamer lines as a seabird bycatch mitigation technique in longline fisheries and CCAMLR streamer line requirements. CCAMLR Science 11,189-201.

Melvin, E.F. 2003. Streamer lines to reduce seabird bycatch in longline fisheries. Washington Sea Grant Program, WSG-AS 00-33.

Melvin, E.F. and Baker, G.B. 2006. *Summary Report: Seabird By-catch Mitigation in Pelagic Longline Fisheries Workshop*. Museum of Natural History, Royal Society Room, Hobart, Tasmania, October 14, 2006. http://wsg.washington.edu/mas/pdfs/Pelagic_Workshop_Rep.pdf downloaded 7 February 2009

Norden, W.S. and Pierre, J.P. 2007. Exploiting sensory ecology to reduce seabird by-catch. Emu 107, 38-43.

Robertson, G., McNeill, M., Smith, N., Wienecke, B., Candy, S. and Olivier, F. 2006. Fast-sinking (integrated weight) lines reduce mortality of white-chinned petrels (Procellaria aequinoctialis) and sooty shearwater (Puffinus griseus) in demersal longline fisheries. Biological Conservation 132, 458-471.

SC-CAMLR 2005. Report of the twenty-fourth meeting of the Scientific Committee of the Commission for the Conservation of Marine Living Resources. Commission for the Conservation of Marine Living Resources, Hobart.

Appendix 1:

Intellectual Property

AHi Enterprises Pty Ltd has sole rights to all patents and IP attached to the Smart Hook system.

No additional IP has been identified as result of the information arising from the research.

The value of the information in this research cannot be quantified due to the broad application across fisheries, the environment and commercial interests.

Appendix 2:

Staff

No staff was directly employed for this project. Private consultants and companies were contracted to perform the trials and individuals provided in kind contributions to assist.

Private consultants included, Barry Baker from Latitude 42 Environmental Consultants Pty Ltd, Dr Kerstin Fritches from University of Queensland.

Service providers included Encounter Kaikoura.

In kind contributors included; Underwater World, NMFS, Great Barrier Reef Tuna

Appendix 3

Raw Data

. Response of three species-groups of seabirds to baited smart hooks.

	Response	Large albatrosses		Smaller albatrosses		Giant petrels		All seabirds	
	Bait: dead squid	**No of observations (% of total)**							
0	no response	**17**	0.71	**5**	0.23	**16**	0.80	**38**	0.58
1	bird moves toward hook, then shows no further interest	**4**	0.17	**12**	0.55	**2**	0.10	**18**	0.27
2	bird touches smart hook/bait	**1**	0.04	**1**	0.05	**2**	0.10	**4**	0.06
3	bird attempts to eat bait, does not swallow	**2**	0.08	**4**	0.18			**6**	0.09
4	bait/smart hook swallowed, then regurgitated								
5	bait/smart hook swallowed, retained								
	Total	**24**		**22**		**20**		**66**	
	Bait: dead fish								
0	no response	**19**	0.68	**12**	0.55	**19**	0.95	**50**	0.71
1	bird moves toward hook, then shows no further interest	**7**	0.25	**9**	0.41	**1**	0.05	**17**	0.24
2	bird touches smart hook/bait	**2**	0.07	**1**	0.05			**3**	0.04
3	bird attempts to eat bait, does not swallow								
4	bait/smart hook swallowed, then regurgitated								
5	bait/smart hook swallowed, retained								
	Total	**28**		**22**		**20**		**70**	

Sink rate of smart hook with Japanese style conventional long-line hook baited with large squid.

Test No	Sink time to 12 m	Sink Rate
1	23	0.52
2	23	0.52
3	24	0.50
4	23	0.52
5	19	0.63
6	21	0.57
7	24	0.50
8	22	0.55
9	23	0.52
10	23	0.52
Mean Sink Rate (m/sec)		**0.54**

Catch & Effort Data

Set #	Total Hooks Set	Smart Hooks set	Total Shields attached	Total # Fish Caught	Normal Hook catch	Species	# Smart Hook shield Caught Fish	Normal Hook CPUE	Smart Hook Shields CPUE	Smart hook Catch increase
1	500	50	50	6	6	Mahi	0			
2	486	50	0	25	23	YFT	0			
				28	25	BET	0			
				3	3	Mahi	0			
3	500	100	100	8	7	YFT	1			
				6	6	Mahi	0			
				1	1	SF	0			
4	500	100	0	5	4	YFT	0			
				3	2	BET	0			
5	400	150	150	11	9	YFT	2			
				1	1	BET	0			
				5	2	Mahi	3			
				1	0	SHARK	1			
				6	6	ALB	0			
6	500	150	0	10	7	YFT	0			
				2	2	BET	0			
7	500	150	150	15	6	YFT	9			
				10	6	BET	4			
				4	2	SHARK	2			
				1	1	RUD	0			
				1	1	SF	0			
TOTAL	3386	750	450	152	120		22	0.0443	0.0488	1.102
%		22.10%	13.29%		78.90%		14.47%			

Attachment 1

Testing of the ‘Smart Hook’ Seabird By-catch Mitigation Device

Environmental
Consultants Pty Ltd

Testing of the 'Smart Hook' Seabird Bycatch Mitigation Device — Phase 1

Report prepared for AHI Enterprises

by Barry Baker

May 2009

Testing of the 'Smart Hook'
Seabird Bycatch Mitigation Device — Phase 1

Introduction

Each year many thousands of seabirds are accidentally killed on longline hooks when birds, attracted to fishing vessels by discards and baits, ingest baited hooks and subsequently drown (Baker et al. 2002). While most mortality occurs directly when birds are caught during line-setting and, less commonly, hauling, seabirds may also die after they are released with critical injuries, or following ingestion of fishing hooks when birds eat discarded baits and fish heads containing hooks.

The level of longline-related mortality is such that longline fishing has been identified as a major threat affecting albatrosses (Gales 1998) and the larger petrels and shearwaters (e.g. Patterson and Hunter 1998; Baker and Wise 2005), causing widespread declines in populations throughout the world (Alexander et al. 1997; Birdlife International 1995; Croxall 1998; Delord et al. 2005; Gales 1998; Nel et al. 2002; Poncet et al. 2006; Tuck et al. 2001). Most of the larger albatrosses and petrels that breed and forage within the southern hemisphere are threatened by longline fishing (Gales 1998).

A range of mitigation measures for reducing the incidental catch of seabirds in longline fisheries have been developed (Brothers et al. 1999; Dietrich et al. 2004; Bull 2007) that can be employed according to circumstance. They include night setting; line weighting; seasonal and/or area closures; bird scaring lines; controlling offal discharge; and bait thawing. These measures focus on reducing by-catch during the critical period of setting following release of the bait from the stern of the longline vessel until it has sunk out of reach of diving seabirds by increasing the sink rate of bait; deterring birds from foraging where baits are being set; blocking access to baits, and minimising the congregation of seabirds around vessels. Each has different attributes, costs and potential to successfully reduce seabird catch. Some measures such as night-setting have been consistently successful in a number of longline fisheries (Baker and Wise 2005; Gales et al. 1998; Gilman et al. 2005; Klaer and Polacheck 1997; McNamara et al. 1999; SC-CAMLR 2005), while the effectiveness of others has varied between vessels and seabird species (ACAP Seabird Bycatch Working Group 2007).

While considerable progress has been made in mitigating bycatch in demersal longline fisheries (e.g. Moreno et al. 2007), principally through the development of effective bird scaring lines (Melvin 2003; Melvin et al. 2004), Integrated Weight Line in autoline systems (Robertson et al. 2006), night setting and seasonal closures (SC-CAMLR 2005), proven and accepted seabird avoidance measures in pelagic fisheries require substantial improvement. In 2007, ACAP's Seabird By-catch Working Group reviewed available research on seabird by-catch mitigation measures for pelagic longline fishing (ACAP Seabird Bycatch Working Group 2007; also see Melvin and Baker 2006). They concluded that night setting is currently the only mitigation measure proven to be widely effective with pelagic longline gear, but its widespread adoption is constrained because it is considered to reduce operational efficiency when targeting some pelagic fish species.

In an attempt to address this situation, AHI Enterprises have been working on the development of mitigation device that will significantly reduce seabird bycatch in pelagic longline fisheries in particular, but will also have utility in other longline gear types. Resulting from this work is a device that is known as the Smart Hook System. This system is a new innovation designed and developed to revolutionize the mitigation of seabird and turtle interactions in long-line fishing by the prevention of hooking during the longline setting process in a simple, costs effective manner. It functions like no other mitigation measure by a patented system that allows a barrier to be attached to the baited hook, preventing the hooking of seabirds & turtles during setting of long lines. The non-polluting, degradable barrier detaches from the hook after a short period of time, allowing fish to be caught after the baited hook has passed beyond the normal diving and feeding depths of most seabirds & turtles.

Latitude 42 Environmental Consultants Pty Ltd has been engaged by AHI Enterprises to examine the mitigation capability of the smart hook system as a seabird bycatch mitigation device for the pelagic longline fishing technique. The purpose of Phase 1 of the project was to qualitatively assess the efficacy of the ‘Smart Hook’ prior to undertaking a more comprehensive scientific study at a later stage. Analysis of results of this assessment will be essential in determining if modifications of the design concept are necessary prior to proceeding to further testing and full commercial production and deployment.

Methods

Field work to test the efficacy of the ‘Smart Hook’ System was carried out at off the coast of Kaikoura, South Island, New Zealand. Kaikoura is a well-known seabird ‘hotspot’ that is readily accessible for both seabird observation and research work. It is an area that is routinely frequented by a number of albatross and petrel species that are known to freely interact with commercial fisheries.

All testing was carried out during the morning of 23 July 2008 from the vessel *Encounter II*, an 8.8 metre monohull Stabi Craft that was chartered specifically for the fieldwork. We tested the ‘Smart Hook’ System in a series of trials where we placed baited Smart Hooks near individual seabirds that were feeding on the water adjacent to the vessel. Gear consisted of 2mm monofilament branchline 12 m in length, tied to and additional 15m of monfilament. Japanese style conventional longline hooks, standard circle hooks and US circle hooks were baited with either large squid (200mm) or pieces of barracuda (tail section) of similar length, and inserted into the Smart Hook barrier (Figure 1). The smart hook barrier and unbaited hook weighed 40g. To further protect seabirds in the unlikely detachment of the barrier, all sharp hook-ends were blunt. The seabird assemblage in the area on the day comprised <u>northern giant-petrel</u> (*Macronectes halli*), <u>southern giant-petrel</u> (*M. giganteus*), cape petrel (*Daption capense*), <u>Antipodean albatross</u> *D. antipodensis gibsoni*), <u>northern royal albatross</u> (*D. sanfordi*), <u>southern royal albatross</u> (*D. epomophora*), <u>white-capped albatross</u> (*Thalassarche steadi*), <u>Salvin’s albatross</u> (*T. salvini*), <u>Buller’s Albatross</u> (*T. bulleri*), <u>black-browed albatross</u> (*T. melanophrys*), <u>Campbell’s albatross</u> (*T. impavida*), fairy prion (*Pachyptila turtur*), Hutton’s shearwater (*Puffinus huttoni*) and kelp gull (*Larus dominicanus*)[15]. Weather conditions were cool (15^{0}C) with high cloud and a light south-westerly winds.

Squid and fish baits were presented only to species that were known to freely interact with longline gear, with the species grouped into three categories:

1. large albatrosses (*Diomedea* spp.);

2. smaller albatrosses (*Thalassarche* spp.); and

3. giant petrels (*Macronectes* spp.).

Although we were also intending to test the Smart Hook against White-chinned and other *Procellaria* spp. petrels, and larger *Puffinus* shearwaters, there were none of these species present to permit this.

We approached seabirds in two ways. Birds were either attracted to the boat by chumming, or the boat was positioned adjacent to shark fishing vessels that were hauling nets and processing fish. The resultant discarding of offal by the fishing vessels, or attraction of the ‘chum’ ensured at least 100 birds were in the area at all times during the trial. We then threw baited hooks toward and within 5m of individual birds that were actively feeding near the boat and categorised response variables as:

0. no response

1. bird moves toward Smart Hook, then shows no further interest;

2. bird touches Smart Hook/bait;

3. bird attempts to eat bait but does not swallow Smart Hook;

4. bird ingests Smart Hook and bait, regurgitates gear; and

5. bird ingests Smart Hook and bait, retains gear.

---

[15] The species underlined have been recorded as bycatch in Australian and NZ fisheries in recent years (Australian Fisheries Management Authority unpublished data; Norden and Pierre 2007)

We presented both squid and fish bait types to at least 20 individuals of each of the three seabird categories, to provide a minimum of 120 observations on which to evaluate the response of seabirds to the smart hook.

Sink rate tests of Smart Hook gear and a Japanese style conventional longline hook baited with squid were carried out using a modified bottle test (CCAMLR 2006). Briefly, Smart Hook gear was attached to one end of a 12 m length of 2 mm monofilament line, and the other end of the line securely attached to the neck of an empty 1000 ml plastic bottle. The bottle was then attached to a length of twine. The bottle and the attached smart hook gear was then deployed in the water. While the hook was sinking the bottle lay flat on the water, but once the smart hook reached 12 m depth and the line under tension, the bottle was pulled under the water. The time at which the bottle entered the water was recorded as t1 in seconds. The time at which the bottle was observed to be pulled under the water was recorded as t2 in seconds. The result of the test was calculated as follows:

Sink rate = 12 / (t_2 - t_1).

A total of 10 sink rate tests were carried out in inshore waters while the boat was drifting (engine off) in a 2m swell.

Figure 1. Smart Hook and Japanese style conventional longline hook baited with large squid, used in the trial to qualitatively assess the efficacy of the 'Smart Hook' system.

Results

Smart hooks baited with dead squid and dead fish were presented to a total of 66 and 70 seabirds, respectively (squid — 24 large albatrosses, 22 small albatrosses, and 20 giant petrels; fish — 28 large albatrosses, 22 small albatrosses, and 20 giant petrels) (Table 1). In general, the rapid sink rate of the baited smart hook was such that unless baits landed within less than a metre of a bird, it sank so rapidly that birds appeared unaware or disinterested in pursuing it (see results on sink rates below).

There were no observations of Category 4 or 5 interactions with any of the species groups during the total of 136 observations. For large albatrosses, the most frequent observation for both squid and fish baits was either no response (Category 1, 71% and 68% respectively) or a move toward the bait and then loss of interest (Category 2, 17% and 25% respectively). Birds only attempted to eat squid baits (Category 3) on 2 of 24 observations (8%), but lost the bait during attempts to manipulate the position of it in their bills when it sank beyond their reach (Table 1). On one occasion a baited smart hook held up by a smaller albatross was then taken by a large albatross, but was subsequently lost and sank beyond access depth in the ensuing squabble by both birds. Large albatrosses were not observed attempting to eat fish baits (Category 3).

Smaller albatrosses were more adept at accessing baits, with birds attempting to eat squid baits (Category 3) in 4 (18%) of 22 observations. They also moved toward baited hooks (Category 2) on 55% of observations when both squid and fish baits were deployed (Table 1). Giant petrels were the less adept at accessing baited Smart Hooks of the three species groups observed. There was no response in 80% and 95% of observations of squid and fish baits, respectively, and birds moved toward baits (Category 1) in only 10% and 5% of observations for the same bait types.

When results are pooled for all species groups, no response was observed in 58% and 71% of observations for squid and fish baits respectively, and 27% and 24% of birds moved toward the bait and then showed no further interest (Category 1) for the same bait types. For Category 2 and 3 interactions, the response for squid baits was 6% and 9%, and 4% and 0% for fish baits (Table 1).

Table 1. Response of three species-groups of seabirds to baited smart hooks.

Response		Large albatrosses		Smaller albatrosses		Giant petrels		All seabirds	
Bait: dead squid		No of observations (% of total)							
0	no response	**17**	0.71	**5**	0.23	**16**	0.80	**38**	0.58
1	bird moves toward hook, then shows no further interest	**4**	0.17	**12**	0.55	**2**	0.10	**18**	0.27
2	bird touches smart hook/bait	**1**	0.04	**1**	0.05	**2**	0.10	**4**	0.06
3	bird attempts to eat bait, does not swallow	**2**	0.08	**4**	0.18			**6**	0.09
4	bait/smart hook swallowed, then regurgitated								
5	bait/smart hook swallowed, retained								
	Total	**24**		**22**		**20**		**66**	
Bait: dead fish									
0	no response	**19**	0.68	**12**	0.55	**19**	0.95	**50**	0.71
1	bird moves toward hook, then shows no further interest	**7**	0.25	**9**	0.41	**1**	0.05	**17**	0.24
2	bird touches smart hook/bait	**2**	0.07	**1**	0.05			**3**	0.04
3	bird attempts to eat bait, does not swallow								
4	bait/smart hook swallowed, then regurgitated								
5	bait/smart hook swallowed, retained								
	Total	**28**		**22**		**20**		**70**	

Mean sink rate of smart hooks baited with dead squid was 0.54 metres per second (range 0.5 — 0.63 m/sec, Table 2).

Table 2. Sink rate of smart hook with Japanese style conventional longline hook baited with large squid.

Test No	Sink time to 12 m	Sink Rate
1	23	0.52
2	23	0.52
3	24	0.50
4	23	0.52
5	19	0.63
6	21	0.57
7	24	0.50
8	22	0.55
9	23	0.52
10	23	0.52
Mean Sink Rate (m/sec)		**0.54**

Conclusion

The performance of the Smart Hook was impressive in the presence of abundant and actively feeding seabirds. When deployed the baited hooks sank so quickly that I formed the opinion that many birds were barely aware that the baited hooks represented a food source. The test protocol was to place baited smart hooks within 5 m. of foraging seabirds, but it was only when baits landed within a metre of birds that they displayed any real interest, and attempted to approach (Category 1 or 2) or attack (Category 3) a baited hook. Only six of the 136 birds presented with the smart hook managed to grasp a bait and attempted to feed upon it, but when this happened baits were not retained for long. In all cases squid baits were involved and birds appeared to break a piece off the squid and let the remainder go, at which stage it sank. The action of the birds attacking the bait did not dislodge the Smart Hook barrier and thus expose the birds to the risk of becoming hooked.

The mean sink rate of the Smart Hook (0.54 m/sec) greatly exceeded that observed in unpublished sink rate experiments carried out using dead and live bait attached to hooks and branchlines with 60 g leaded swivels placed between 2 and 4 m from the hook (G.Robertson unpublished data). These trials were conducted on a chartered vessel (not fishing commercially) but under operational fishing conditions, and sink rates ranged from 0.14 — 0.22 m/sec. In future work it is intended to conduct further trials to ascertain the sink rates of the smart hook attached to longline gear under operational conditions and using time depth recorders. While improving line sink rate is not the prime design mechanism for avoiding or minimising seabird bycatch with the Smart Hook, it is likely to further enhance the capabilities of this system. I envisage an operational situation where fewer birds are able to access baits because of increased sink rate but, when they do, they are restricted from accessing the hook and thus avoid capture.

The purpose of this project was to qualitatively assess the efficacy of the ‘Smart Hook’ prior to undertaking a more comprehensive scientific study. Based on the observations reported upon here, I can see no reason at this stage to modify the design of the prototype Smart Hook system. I believe it is now appropriate to proceed to a more extensive evaluation of the system under commercial fishing operations, where the Smart Hook can be tested against conventional fishing gear and the impact on bycatch reduction more thoroughly assessed.

Acknowledgements

I am grateful to the assistance provided by Encounter Kaikoura, particularly Dennis and Lynette Buurman, for essential field support including provision of a vessel. Hans Jusseit constructed the longline gear and assisted with the field tests. Graham Robertson provided comments both during the experimental design phase and after the completion of field work that were helpful in compiling the report.

References

ACAP Seabird Bycatch Working Group. 2007. Report of the first meeting of the Seabird Bycatch Working Group of the Agreement on the Conservation of Albatrosses and Petrels, Valdivia, Chile, 17-18 June 2007. ACAP AC3 Doc.14 Rev 5.

Alexander, K., Robertson, G. and Gales, R. 1997. *The incidental mortality of albatrosses in longline fisheries.* Australian Antarctic Division, Tasmania. 44 pp.

Baker, G. B., Gales, R., Hamilton, S. and Wilkinson, V. 2002. Albatrosses and petrels in Australia: a review of their conservation and management. Emu 102, 71–97.

Baker, G.B. and Wise, B.S., 2005. The impact of pelagic longline fishing on the flesh-footed shearwater Puffinus carneipes in Eastern Australia. Biological Conservation 126, 306–316.

BirdLife International 1995. *Global Impacts of Fisheries on Seabirds.* A paper prepared by Birdlife International for the London Workshop on Environmental Science, Comprehensiveness and Consistency in Global Decisions on Ocean Issues. 30 November – 2 December 1995.

BirdLife International, 2004a. Threatened birds of the World 2004. CD-ROM. Cambridge, UK, BirdLife International

BirdLife International. 2004b. Tracking ocean wanderers: the global distribution of albatrosses and petrels. Results from the Global Procellariiform Tracking Workshop, 1–5 September, 2003, Gordon's Bay, South Africa. Cambridge, UK; BirdLife International; 2004.

CCAMLR. 2007. Schedule for conservation measures in force, 2006–2007. Commission for the Conservation of Antarctic Marine Living Resources, Hobart.

Croxall, J.P. 1998. Research and Conservation: a future for albatrosses? Pp. 269–290 in *Albatross: Biology and Conservation*. Robertson, G. and Gales, R. (eds.). Surrey Beatty and Sons, Chipping Norton.

Croxall, J.P. and Gales, R.P. 1998. An assessment of the conservation status of albatrosses. Pp. 46–65 in *Albatross: Biology and Conservation*. Robertson, G. and Gales, R. (eds.). Surrey Beatty and Sons, Chipping Norton.

Gales, R. 1998. Albatross populations: status and threats. Pp. 20–45 in *Albatross: Biology and Conservation*. Robertson, G. and Gales, R. (eds.). Surrey Beatty and Sons, Chipping Norton.

Melvin, E. F., Sullivan, B., Robertson, G. and B. Wienecke. 2004. A review of the effectiveness of streamer lines as a seabird bycatch mitigation technique in longline fisheries and CCAMLR streamer line requirements. CCAMLR Science 11,189-201.

Melvin, E.F. 2003. Streamer lines to reduce seabird bycatch in longline fisheries. Washington Sea Grant Program, WSG-AS 00-33.

Melvin, E.F. and Baker, G.B. 2006. *Summary Report: Seabird By-catch Mitigation in Pelagic Longline Fisheries Workshop*. Museum of Natural History, Royal Society Room, Hobart, Tasmania, October 14, 2006. http://wsg.washington.edu/mas/pdfs/Pelagic_Workshop_Rep.pdf downloaded 7 February 2009

Norden, W.S. and Pierre, J.P. 2007. Exploiting sensory ecology to reduce seabird by-catch. Emu 107, 38-43.

Robertson, G., McNeill, M., Smith, N., Wienecke, B., Candy, S. and Olivier, F. 2006. Fast-sinking (integrated weight) lines reduce mortality of white-chinned petrels (Procellaria aequinoctialis) and sooty shearwater (Puffinus griseus) in demersal longline fisheries. Biological Conservation 132, 458-471.

SC-CAMLR 2005. Report of the twenty-fourth meeting of the Scientific Committee of the Commission for the Conservation of Marine Living Resources. Commission for the Conservation of Marine Living Resources, Hobart.

Bjorndal, K. and Martins, H. (2003). Estimates of survival probabilities for oceanic-stage loggerhead sea turtles (Caretta caretta) in the North Atlantic. *Fisheries Bulletin* **101**, 732-736.

Bolten, A. and Bjorndal, K. (2005). Experiment to evaluate gear modification on rates of sea turtle in the swordfish longline fisheries in the Azores - Phase 4. *Final Report, NMFS, USA*.

Bugoni, L., Neves, T., Leite Jr., N., Carvalho, D., Sales, G., Furness, R., Stein, C., Peppes, F., Giffoni, B. and Monteiro, D. (2008). Potential bycatch of seabirds and turtles in hook-and-line fisheries of the Itaipava fleet, Brazil. *Fisheries Research* **90**, 217-224.

Lewison, R. L. and Crowder, L. B. (2007). Putting longline bycatch of sea turtles into perspectve. *Conservation Biology* **21**, 79-86.

Stokes, L., Epperly, S., Belskis, L. and Hataway, D. (2006). Morphometric parameters and ontogeny of the oral cavety in loggerhead sea turtles (Caretta Caretta). In *Sea Turtle Symposium*. Crete, Greece.

Watson, J., Epperly, S., Shah, A. and Foster, D. (2005). Fishing methods to reduce sea turtle mortality associated with pelagic longlines. *Canadian Journal of Fisheries and Aquatic Sciences* **62**, 965-981.

Attachment 2

Testing The Bycatch Mitigation Efficacy Of the *Smart Hook* For Sea Turtles.

UniQuest

Prepared for

Ahi Enterprises Pty Ltd

Subject

Testing the Bycatch Mitigation Efficacy of the Smart Hook for Sea Turtles

Author

Dr Kerstin Fritsches

31 March 2008
UniQuest Project No: 15191

UniQuest Pty Limited

UniQuest Pty Limited
Consulting & Research
(A.B.N. 19 010 529 898)

Level 7, GP South Building
Staff House Road
University of Queensland
Queensland 4072

Postal Address:
PO Box 6069
St Lucia
Queensland 4067

Telephone: (61-7) 3365 4037
Facsimile: (61-7) 3365 7115

UniQuest Pty Limited
Consulting & Research
(A.B.N. 19 010 529 898)

Level 7, GP South Bldg
Staff House Road
The University of Queensland
Queensland 4072

Postal Address:
PO Box 6069
St. Lucia
Queensland 4067

Telephone: (61-7) 3365 4037
Facsimile: (61-7) 3365 7115

UniQuest Project No.	**15191**
Report Prepared for:	**Mr. Hans Jusseit** **Ahi Enterprises Pty Ltd**
Subject:	**Testing the Bycatch Mitigation Efficacy of the Smart Hook for Sea Turtles**
Date:	**31 March 2008**
Report Prepared By:	**Dr Kerstin Fritsches**

Signed for and on behalf of UniQuest Pty Limited

Gary Heyden

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY 2

2. INTRODUCTION 3

3. METHODS 4

3.1 Behavioral work 4

3.2 Anatomical data used to estimate ability of sea turtles to swallow the Smart Hook 6

4. RESULTS 7

5. CONCLUSIONS AND RECOMMENDATIONS 10

6. ACKNOWLEDGMENTS 12

7. REFERENCES 12

1. EXECUTIVE SUMMARY

The response of captive sea turtles was tested when presented with a new longline bycatch mitigation device, the *Smart Hook*. During 46 trials, resulting in more than 400 interactions of two green turtles and eight loggerhead sea turtles with the device, no hooking in the mouth, swallowing of the *Smart Hook* or foul-hooking in other body parts were observed. Also, none of the animals tested was able to damage the device. Extrapolation from oral anatomy data suggests a minimum carapace length of 70cm for loggerhead sea turtles and close to 100cm for green turtles is required before animals are physically able to swallow a *Smart Hook*, sizes which are above the average recorded as interacting with longline gear. During the testing a design problem was identified and can be rectified by a minor change to the device. The results show that the *Smart Hook* is highly effective in preventing hooking of the mouth and other body parts of green and loggerhead sea turtles.

2. INTRODUCTION

This study aims to assess qualitatively the response of sea turtles to the *Smart Hook*, a hook guard designed to prevent bycatch, chiefly of sea birds and sea turtles, in the initial phase of setting longline gear. This is one of two pilot studies with the second study focussed on sea bird responses to the device. The pilot studies will be followed by field studies, testing the *Smart Hook* in off-shore longlining operations.

Sea turtle populations world-wide are under threat and sea turtle bycatch by longline gear places further pressure on survival rates of these endangered or threatened species (Lewison and Crowder, 2007). Loggerhead and leatherback sea turtles are the main turtle species found in longline bycatch. Loggerhead sea turtles are carnivorous and appear to be attracted to the bait with the majority of animals either hooked in the mouth or with hooks ingested (e.g. Watson et al., 2005; Bolten and Bjorndal, 2005). With access to a number of captive loggerhead sea turtles at the National Marine Fisheries Service Facility in Galveston, Texas, this study largely concentrated on loggerhead sea turtles' reaction to the *Smart Hook*. Leatherback sea turtles are also part of the incidental bycatch (e.g. Watson et al., 2005) as they are the most oceanic and temperate of the sea turtle species, with their habitat overlapping with a large proportion of longline-fishing activities worldwide. Larger animals cannot be kept in captivity, making it impossible to test the *Smart Hook* on this species. Green turtles are mainly herbivorous, however they are also found, to a smaller extent, in longline fisheries bycatch (Bugoni et al., 2008). Access to larger green turtles kindly provided by Underwater World, Mooloolaba, Queensland, allowed us to test green turtles' reaction to the *Smart Hook*, in addition to that of loggerheads.

The *Smart Hook* design includes a metal cap-like shield that is attached to the hook with a pin that quickly corrodes in saltwater (Fig 1). The shield covers the tip of the hook during the initial time of the gear in the water, while also providing weight to sink the baited hook. Once the hook is deployed and has sunk to its designated depth, the shield is released from the hook by rapid corrosion and fish can be caught with the now functional hook.

The aim of this study was to observe how sea turtles respond to the *Smart Hook* when presented, whether the device indeed prevents hooking of the animal and whether the animals can disable the *Smart Hook* in any way. To allow for such close-up observations, captive turtles were used in enclosed aquarium facilities.

3. METHODS

3.1 Behavioural work

Animals:

Two species of marine turtles were tested, the green turtle *Chelonia mydas* and the loggerhead sea turtle *Caretta caretta.* Information on all animals tested is shown in Table 1.

Turtle number	Carapace length (SCL, cm)	age	Type of test under-taken	Comment
Green 1	43	unknown	Hook types and bait	Wild, rehab turtle
Green 2	80	unknown	Hook types and bait	Wild, rehab turtle
Loggerhead 1	47	3y	Hook types and bait + racetrack	Raised in captivity
Loggerhead 2	46	3y	Hook Types and bait	Raised in captivity
Loggerhead 3	46	3y	Hook Types and bait	Raised in captivity
Loggerhead 4	46	3y	Hook types and bait + racetrack	Raised in captivity
Loggerhead 5	47	3y	Hook types and bait + racetrack	Raised in captivity
Loggerhead 6	47	3y	Hook Types and bait	Raised in captivity
Loggerhead 7	47	3y	Hook Types and bait	Raised in captivity
Loggerhead 8	56	4y	Hook Types and bait	Raised in captivity

Table 1. Overview of the sea turtles tested

Green turtles (n=2) were accessed at Underwater World, Mooloolaba, Queensland in June 2008 with the work covered under DPI&F permit CA 2008/03/251. Both turtles had been sick or injured at their arrival at Underwater World but had fully recovered by the time of the trials, and were moving and feeding well. No further green turtles could be accessed during the testing period.

Loggerhead sea turtles (n=8) were tested at the National Marine Fisheries Service (NMFS) Sea Turtle Facility in Galveston, Texas, USA in October / November 2008. This facility raises sea turtles from hatchlings for up to 4 years in captivity to provide testing facilities for bycatch mitigation devices and other sea turtle research.

Testing environment

Underwater World: Both turtles were tested in a shallow holding bay (2.5 x 2.5m, depth 1.5m). Animals were allowed to acclimatise for at least 30min before testing commenced.

NMFS Facility: Eight turtles were tested in their circular holding tanks (1.8m diameter, 0.9m high) located in an indoor aquarium room. The tanks received a constant flow of clean seawater at a constant temperature (28˚C) and the animals had been kept in this environment since their arrival as hatchlings.

Three turtles were transferred to the "racetrack" (6 x 1.8m, 0.9m deep) in the same facility to test their ability to catch the *Smart Hook* moving at its sinking speed. Animals were allowed to acclimatise to this tank for at least 1h before testing commenced.

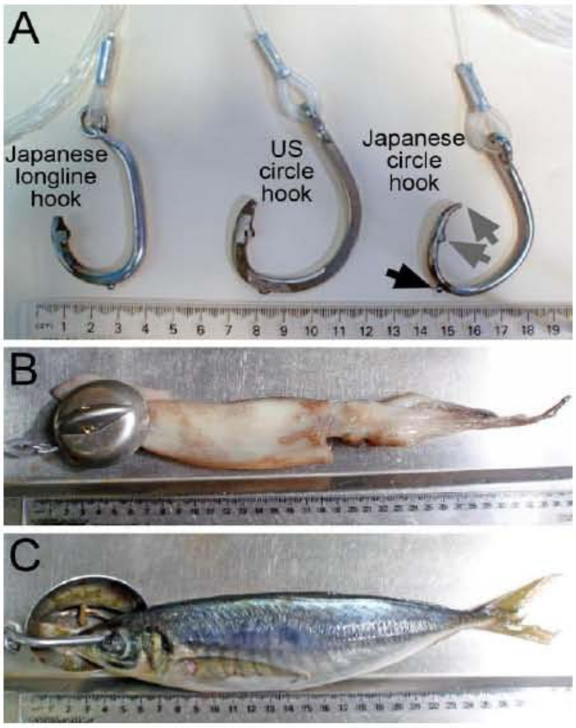


Fig 1. **A**: Different hook types showing blunted barbs and tips (grey arrows) and the extrusion that holds the hook in place in the *Smart Hook* shield (black arrow). **B, C**: *Smart Hook* baited with squid and fish.

***Smart Hook* configurations tested (Fig 1)**

The *Smart Hook* guard was the same for all configurations and consisted of a soft steel custom shaped cap-like shield, 64mm in diameter and 1.3mm thick, weighing between 34 and 40g. For the experiments the pin that holds the shield in place was made from brass to prevent corrosion during the testing. The dimensions of the pin were identical to those of the pins used in the functioning *Smart Hook*. Under the shield, the hook tips were blunted and barbs flattened to minimise risk of injury to the sea turtles during the trials.

Hook types:

1. US Circle Hook; size Mustad 16/0
2. Japanese Circle Hook; size 4
3. Japanese Longline Hook; size 3.6

Bait Types:

1. Squid bait
2. Fish (sardines and yellowtail for green turtles, spanish sardines for loggerhead sea turtles)

Both squid and fish baits were tested, however emphasis was placed on using squid bait, as both the captive green and loggerhead sea turtles were known to prefer squid to fish as food (Underwater World and NMFS Facility staff, personal communication).

Testing procedures and analysis

- *Experiment 1 - Testing interactions with the stationary Smart Hook*

Each hook and bait configuration was presented to the animal in mid-water for 5min and the response recorded with a video camera. Interactions were scored based on the video recording (at Underwater World) and in real-time (NMFS Facility) with respect to whether the animal bit the bait, the shield or the hook, and whether the front flippers were used to interact with the *Smart Hook*. A single interaction was defined as the timeframe the animal's mouth was in direct physical contact with the *Smart Hook* or the bait attached.

- *Experiment 2 - Testing interactions with the Smart Hook at natural sink rate*

Pacing out the length of the "racetrack" the *Smart Hook*'s natural sink rate of 0.6m / sec (see results Component 1 by B. Baker) was simulated in the horizontal dimension. Also, a much faster sink rate of 1m / sec was tested with 2 turtles. The *Smart Hook*, using the US circle hook and squid bait, was trailed in the centre of the "racetrack" in mid-water and the loggerhead turtles' response either filmed with a hand-held video camera or recorded on paper in real time. Due to lack of sufficient aquarium space this experiment could not be undertaken with the green turtles.

3.2 Anatomical data used to estimate ability of sea turtles to swallow the Smart Hook

Post-mortem throat dimensions for green turtles were kindly provided by Dr. Kathy Townsend. These were measured on deceased stranded turtles that had been frozen and then thawed for examination. Calipers were used to measure the narrowest dorso-ventral and left-right diameter in the animal's throat. Staff at Underwater World provided measurements of external gape height at the front of the mouth in living green turtles using a dog gag and digital calipers. Measurements on oral anatomy of living loggerhead turtles were kindly provided by Dr. Lesley Stokes using the animals at the NMFS facility during 2003-2004 (Stokes et al., 2006).

4. RESULTS

Behavioural observations:

When presented with the baited *Smart Hook* loggerhead turtles predominately bit the bait first and aimed to remove it from the hook (87.5% for loggerhead sea turtles; 4 out of 32 animals). The two green turtles bit or touched the shield first in 55% (6 out of 11) of first interactions. Turtles of both species proceeded to try to remove the bait from the *Smart Hook*. The animals were surprisingly tactile and delicate in their efforts to remove the bait, apparently able to distinguish between the bait and the metal and monofilament components.

A common observation for both species was that the animals used their front flippers to manipulate the bait and the *Smart Hook* (forelimbs were used in 94% (30 of 32) of trials for loggerhead

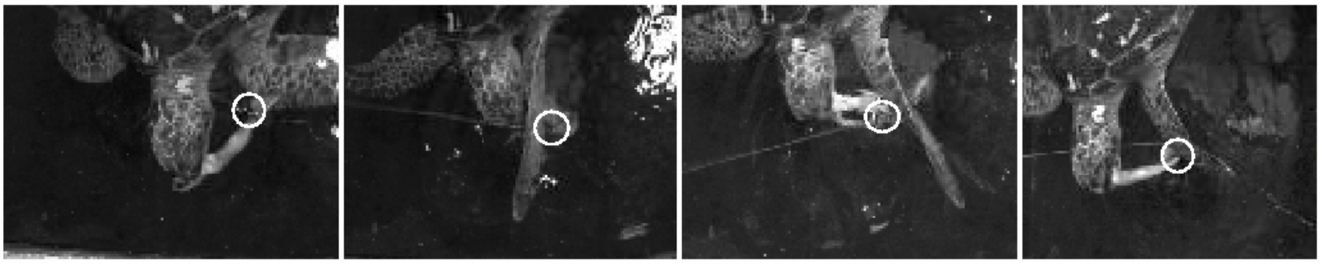


Fig 2. Single frame capture series of a green turtle using its front flipper to help remove squid bait from the *Smart Hook* (white circles indicate position of the *Smart Hook*). Despite frequent use of the forelimb the guard very successfully prevents foul-hooking in the flipper.

turtles and 64% (7 of 11) of trials in green turtles). Green turtles tended to move one or both flippers in a large arch movement to push the *Smart Hook* away. Loggerhead turtles were more delicate in their use of forelimbs, often using a single flipper and specifically the single claw on the inside of the limb to push the shield away while biting the bait. In none of the interactions was hooking or entanglement around the forelimbs or any other body part of the turtles observed as the guard effectively shielded the barb and the tip of the hook (Fig 2).

We tested 3 different hook types, US circle hook, Japanese longline hook and Japanese circle hook, and used both squid and fish as bait (Fig. 1). The *Smart Hook* was effective in preventing hooking for all hook and bait types in all trials undertaken for both the green and the loggerhead sea turtles. Most turtles (8 loggerhead and 1 green turtle tested) preferred squid to fish bait with 130 interactions recorded with squid baited hooks versus 74 interactions seen with fish baited hooks. These were interactions counted both when the bait was present and after the animal had removed the bait. Using squid as bait, the most interactions were recorded with US circle hooks (127 interactions) with Japanese longline hooks attracting 90 interactions and Japanese circle hooks 67 interactions in all trials.

During all interactions that were observed (n=339 for loggerhead sea turtles and n=57 for green turtles), the *Smart Hook* was never ingested. After the animal removed the bait, varying levels of interest in the *Smart Hook* itself were seen. Some of the captive-reared loggerhead turtles did not show any interest at all while others bit the shield or the hook up to 26 times in a 5 min period. The two wild-caught green turtles were mainly uninterested in the *Smart Hook* after bait removal although the second green turtle repeatedly tapped against the shield rather than biting into it. In all cases biting did not cause any damage to the shield and turtles usually released the shield immediately after biting it.

On one occasion a loggerhead sea turtle (Loggerhead 8, the largest one) caught its lower jaw between the hook shank and the *Smart Hook* shield, though the shield successfully protected it from the hook tip. This incident will result in a change of the insertion angle of the hook into the shield, bringing the hook shank and the edge of the shield closer together to prevent such entanglement occurring in the future.

We also tested 3 loggerhead sea turtles in a large "raceway" tank for their interactions with the *Smart Hook* moving at average sinking speed (0.6m/sec). These captive-reared animals were entirely unconditioned and had rarely or never encountered larger bodies of water. However each animal quickly learned to follow the moving bait and caught it easily at sinking speed. We also tested faster speeds (ca. 1m/sec) and the turtles still caught the bait. Interactions with the moving baited *Smart Hook* were very similar to those seen with the stationary device. The turtles first bit the trailing bait, clearly distinguishing between bait and the hook and shield. The animals did not show any aggressive behaviour or more forceful biting of the moving device than that seen in the trials where the *Smart Hook* was kept stationary.

Ability of sea turtles to swallow the *Smart Hook*

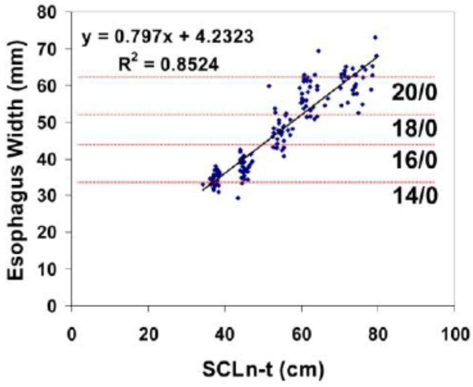


Fig 3. Data from Stokes and colleagues (2006) showing esophagus width measured in living loggerhead sea turtles at different straight carapace lengths (SCL). The horizontal lines indicate width of different Mustad hook sizes.

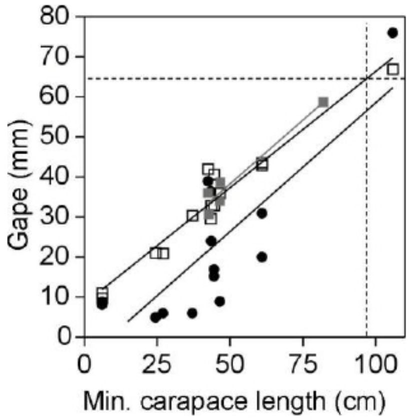


Fig. 4. Data provided by K. Townsend and staff at Underwater World on green turtle esophagus height (black circles) and width (white squares) measured in dead animals and external gape height (grey squares) measured in live turtles. The dotted line indicates the width of the Smart Hook and the corresponding carapace length (esophagus width $R^2 = 0.94$, n=14).

In the behavioural trials no ingestion of the hook and shield was seen in either green or loggerhead sea turtles, however the loggerhead sea turtles available for testing were on the smaller side of the range recorded as encountering longline hooks (Watson et al., 2005; Bugoni et al., 2008). Anatomical data of mouth and throat gape was therefore used here to estimate at which carapace length both green and loggerhead sea turtles would be physically able to swallow a *Smart Hook*. With a diameter of 64mm the *Smart Hook* has a similar width to a 20/0 Mustad 39960D circle hook. According to Stokes and colleagues (2006) loggerhead sea turtles need to reach an average carapace length of over 70cm in order to be able to swallow a 20/0 circle hook when considering esophagus width (Fig 3). Unlike a flat hook, the *Smart Hook* also has a height of 54mm when attached to a 16/0 American circle hook for instance. No information on loggerhead esophagus height was recorded to allow predictions of the effect of the height of the *Smart Hook* on the turtles' ability to swallow the *Smart Hook*, however it is reasonable to assume that the added bulk would hinder swallowing further.

For green turtles Dr. Kathy Townsend and staff from Underwater World kindly provided oral dimension data for both dead and living animals. Compared to loggerhead turtles, green turtles have smaller gapes in relation to carapace length and the data indicates that a green turtle will have to reach a carapace length of close to 100cm before it is physically able to swallow a *Smart Hook* (Fig 4). The largest green turtle (80cm carapace length) tested here never attempted to swallow the *Smart Hook* in the behavioural trials.

5. CONCLUSIONS AND RECOMMENDATIONS

The behavioural trials of captive turtles have shown that the *Smart Hook* successfully prevents both green and loggerhead turtles from getting hooked while interacting with the baited or un-baited device. None of the animals tested were able to remove or destroy the shield despite frequent biting. Most animals showed curiosity and mouthed the device, however in all cases the animals' initial aim was to remove and eat the bait from the device, which they were able to do without contact with the hook tip due to the shield. It was also noted that both green and loggerhead sea turtles actively use their front flippers to help remove bait from the hook, risking foul-hooking in the flippers or the soft flesh of the neck or base of the flipper. The *Smart Hook* prevented such foul-hooking in all cases.

While potential preferences for bait types and hook types were detected here, the highly variable behaviour of individual animals and the artificial presentation of the device to the captive turtles suggest caution in interpreting these preferences for turtle behaviour in the field. The aim of this study was to test whether there was any difference in the effectiveness of the *Smart Hook* when using different hook and bait types and I found the *Smart Hook* to be effective in preventing hooking in all configurations tested.

The size of the shield in the *Smart Hook* will restrict the potential for swallowing to animals of larger carapace size exceeding 70cm for loggerhead sea turtles and close to 100cm for green turtles. The large majority of loggerhead sea turtles interacting with longline gear appear to be below 70 cm (Bjorndal and Martins, 2003; Watson et al., 2005) suggesting they would be too small to swallow the device. Green turtles found in longline bycatch are likely to be much smaller than the theoretical minimum size for swallowing the *Smart Hook* with Bugoni and colleagues (2008) registering their largest animal at 52cm. I note, however, that size estimates were derived from oral anatomy measurements not accounting for active swallowing in the behaving turtle, which might allow somewhat smaller turtles to swallow the device. In the behavioural trials none of the turtles tried to swallow the device.

Ingestion of the hook is a major danger and strongly linked to mortality in sea turtle bycatch; and incidences of ingestion are reduced with increasing hook size (Watson, 2005). Due to the size of the shield, which remains constant regardless of the hook size used, the *Smart Hook* is likely to reduce the number of incidences of ingestion during the deployment phase, especially compared to using smaller, unguarded hooks.

During the trials it became obvious that a modification of the *Smart Hook* design is necessary to reduce the angle between the hook shank and the shield to prevent entanglement in the device. This modification can be easily achieved by moving the position of the extrusion that hold the hook in position within the shield (Fig 1) and such modification should be undertaken to enhance the effectiveness of the *Smart Hook*.

The results obtained from the captive sea turtles outlined above demonstrate that the *Smart Hook* is a highly effective device to prevent hooking of the mouth and other body parts of green and loggerhead sea turtles.

6. ACKNOWLEDGMENTS

Special thanks go to Ben Higgins and his staff at the NMFS Sea Turtle Facility at Galveston, Texas for hosting and supporting the project 6 weeks after Hurricane Ike destroyed most of Galveston. Also the staff at Underwater World provided invaluable access and support for testing the green turtles. Further thanks go to Kathy Townsend, Moreton Bay Research Station; Lesley Stokes, NMFS; Geoff Smith, DPI and Craig McDonald, UniQuest, for helpful discussions and advice. Lastly I would like to thank Hans Jusseit for his help during the trials and the many useful discussions.

7. REFERENCES

Bjorndal, K. and Martins, H. (2003). Estimates of survival probabilities for oceanic-stage loggerhead sea turtles (Caretta caretta) in the North Atlantic. *Fisheries Bulletin* **101**, 732-736.

Bolten, A. and Bjorndal, K. (2005). Experiment to evaluate gear modification on rates of sea turtle in the swordfish longline fisheries in the Azores - Phase 4. *Final Report, NMFS, USA*.

Bugoni, L., Neves, T., Leite Jr., N., Carvalho, D., Sales, G., Furness, R., Stein, C., Peppes, F., Giffoni, B. and Monteiro, D. (2008). Potential bycatch of seabirds and turtles in hook-and-line fisheries of the Itaipava fleet, Brazil. *Fisheries Research* **90**, 217-224.

Lewison, R. L. and Crowder, L. B. (2007). Putting longline bycatch of sea turtles into perspectve. *Conservation Biology* **21**, 79-86.

Stokes, L., Epperly, S., Belskis, L. and Hataway, D. (2006). Morphometric parameters and ontogeny of the oral cavety in loggerhead sea turtles (Caretta Caretta). In *Sea Turtle Symposium*. Crete, Greece.

Watson, J., Epperly, S., Shah, A. and Foster, D. (2005). Fishing methods to reduce sea turtle mortality associated with pelagic longlines. *Canadian Journal of Fisheries and Aquatic Sciences* **62**, 965-981.

TERMS OF REPORT

UniQuest Pty Limited employees and University of Queensland staff and consultants operating with UniQuest will make all reasonable efforts to ensure an accurate understanding of client requirements. The information in reports is based on that understanding, and UniQuest strives to be accurate in its advice and to engage suitably qualified consultants with requisite skills of the highest order.

While all reasonable care will be taken in the preparation of reports, all information, assumptions, and recommendations therein are published, given, made, or expressed on the basis that:

(a) Any liability of any nature which would otherwise exist or arise in any circumstances by reference to any part or any omission from this report is excluded to the maximum extent permitted by law;

(b) Any liability which is unable to be excluded is limited to the minimum sum permitted by law;

(c) These provisions bind any person who refers to, or relies upon, all or any part of a report; and

(d) These provisions apply in favour of UniQuest and its directors, employees, servants, agents and consultants.

The client shall indemnify UniQuest and its directors, employees, servants, agents, consultants, successors in title and assigns against any claim made against any or all of them by third parties arising out of the disclosure of reports, whether directly or indirectly, to a third party.

A laboratory certificate, statement, or report may not be published except in full, unless permission for publication of an approved abstract has been obtained, in writing from the Managing Director of UniQuest.

Samples will be destroyed within 30 days unless collected by the client, or alternative arrangements have been agreed to by UniQuest.

Attachment 3

Operational Performance of the Smart Hook System in a Commercial Tuna Fishing operation.

AHi Enterprises Pty Ltd

Operational Performance of the Smart Hook System in a Commercial Tuna Fishing operation.

By Hans Jusseit
August
2010

"Present Day Solutions For Vital Oceans Tomorrow"
Ahi Enterprises Pty Ltd PO Box 1080, Mooloolaba QLD 4557, Australia Tel: 61-410-499-824
Email: ahienterprises@optusnet.com.au

Table of Contents

Executive Summary ***4***

Background ***5***

Method ***5***

Fishing operations & conditions ***6***

Gear Configuration **7**

Setting & retrieval **8**

Observations ***9***

Fishing operations **9**

Setting **10**

Casting the bait **10**

Retrieval **10**

Interviews **11**

Data ***12***

Data Analysis **12**

Discussion ***12***

Conclusion ***12***

Acknowledgements ***12***

FIG 1 GEAR CONFIGURATION 7
FIG 2 MAINLINE CONFIGURATION 8
TABLE 1 SETTING SEA CONDITIONS 13
TABLE 2 CATCH & EFFORT DATA 14
TABLE 3 CPUE ANALYSIS 15

Ahi Enterprises Pty Ltd PO Box 1080, Mooloolaba QLD 4557, Australia Tel: 61-410-499-824
Email: ahienterprises@optusnet.com.au

Executive Summary

The Smart Hook system was developed to prevent the capture of seabirds & turtles in Tuna Long-line fisheries.

The system comprises a reusable tuna long-line hook that has been modified to allow a specially designed shield to be attached after the hook is baited. The Smart Hook shield was only attached during fishing conducted in daylight hours.

Long-line sets were conducted by adding the Smart hook to the branch line repairs. 150 branch-lines with the Smart Hooks attached were introduced into the fishing gear and used during the fishing trip.

Branch-lines used for the Smart Hook had 12 fathoms of monofilament from the branch-line clip directly to the smart hook. The Smart Hook in this trial was a 3.8 Tuna Long-line hook with smart hook modification. The Smart Hook shield was attached to all Smart Hooks during daylight hours of setting.

The process for setting the gear using the Smart Hook system was to bait the Smart Hook with one or two sardines or a squid then attaching the Smart Hook Shield to the baited hook.

The crew adapted quickly and easily to attaching the shield to the Smart Hook. The crew commented that the baited Smart Hook with shield was easier to cast than an ordinary baited hook and branch line with a lead swivel.

The crew also felt the Smart Hook & shield assisted with retaining bait on the hook when casing and entering the water.

The Captain and crew were interviewed to determine their response to the system, responses were positive with constructive comments.

Analysis of the data shows the Smart hook system increased the CPUE, increasing productivity and economic return. This is believed to be due to an increase in bait retention, resulting in fish having access to more baited hooks,

The Smart Hook system was easily incorporated into the Tuna long-line fishing operations and performed well.

The Smart Hook system performed well under all conditions experienced and can be easily included into Tuna long-line operations, to mitigate the capture of seabirds and turtles.

Background

Tuna Long-lines, worldwide, are responsible for capturing and killing hundreds of thousands of seabirds and turtles each year. This method of fishing is listed as a key threatening process in the survival of seabirds.

The Smart Hook system was developed to prevent the capture of seabirds & turtles by Tuna Long-line fishing.

The system comprises a reusable tuna long-line hook that has been modified to allow a specially designed shield to be attached after the hook is baited. The shield, by design, disarms the hook, prevents ingestion and increases the sink rate, thereby mitigating the threat of capture. The design of the shield provides a release after 10-20 minutes, freeing the baited hook to catch fish.

This report is for the final stage in Phase 1 for “Testing seabird & turtle mitigation efficacy of the smart hook system in tuna long-line fisheries”

The objective of this stage was to “Determine the operational performance of the Smart Hook System in a commercial fishing operation” i.e. tuna long-line operation.

Prior to undertaking this stage the Smart Hook system’s mitigation efficacy on seabirds & turtles was conducted and reported in separate research[16] to minimize the risk of seabird and or turtle mortality.

The testing was conducted on a fishing vessel in the Coral Sea to avoid interaction with the major threatened species common in southern waters.

Method

All seven setting and hauling operations were observed during the fishing trip. Observations included conditions, bird life, baits used, time of setting and catch.

Branch-lines with the Smart Hook attached were introduced randomly after the first set using one and two sardines per hook as well as squid for bait.

The Smart Hook shield was only attached during fishing conducted in daylight hours.

Video and still photographic media was used to record setting operations.

Data was collected and tabled (Table 1) at the end of each set and during the haul, noting the catch.

[16] Latitude42 Environmental Consultants Pty Ltd Testing of the ‘Smart Hook’ Seabird By-catch Mitigation Device by Barry Baker, University of Queensland, Testing The By-catch Mitigation Efficacy Of The *Smart Hook* For Sea Turtles by Dr. Kerstin Fritsches

The captain and crew were interviewed on video to document their assessment of the Smart Hook system in the fishing operation.

Data analysis (Table 2) was undertaken to determine any variation in catch per unit effort (cpue).

Fishing operations & conditions

Weather conditions varied from calm weather on the first day with increasing SE winds to 30 knots, sea and swell rising to two metres and overcast with rainsqualls.

The fishing operation was conducted on FV Rummage owned by Great Barrier Reef Tuna. The vessel was operated by Captain Cameron Keith, a seasoned long-line fisherman with over ten years experience, and an experienced crew of three, including a female crew member, complimented the vessels operations.

As a condition of the fishing permit the vessel is only allowed to carry 500 branch lines at any one time. The vessel was in port for a day, enough time to unload and re-provision, before setting out again.

This provided difficulties in preparing enough fishing gear to set in the first instance as most of the fishing gear was already prepared with only 45 branch lines left to repair. Subsequent settings were conducted by adding the Smart hook to the branch line repairs. 150 branch-lines with the Smart Hooks attached were introduced into the fishing gear.

Gear Configuration

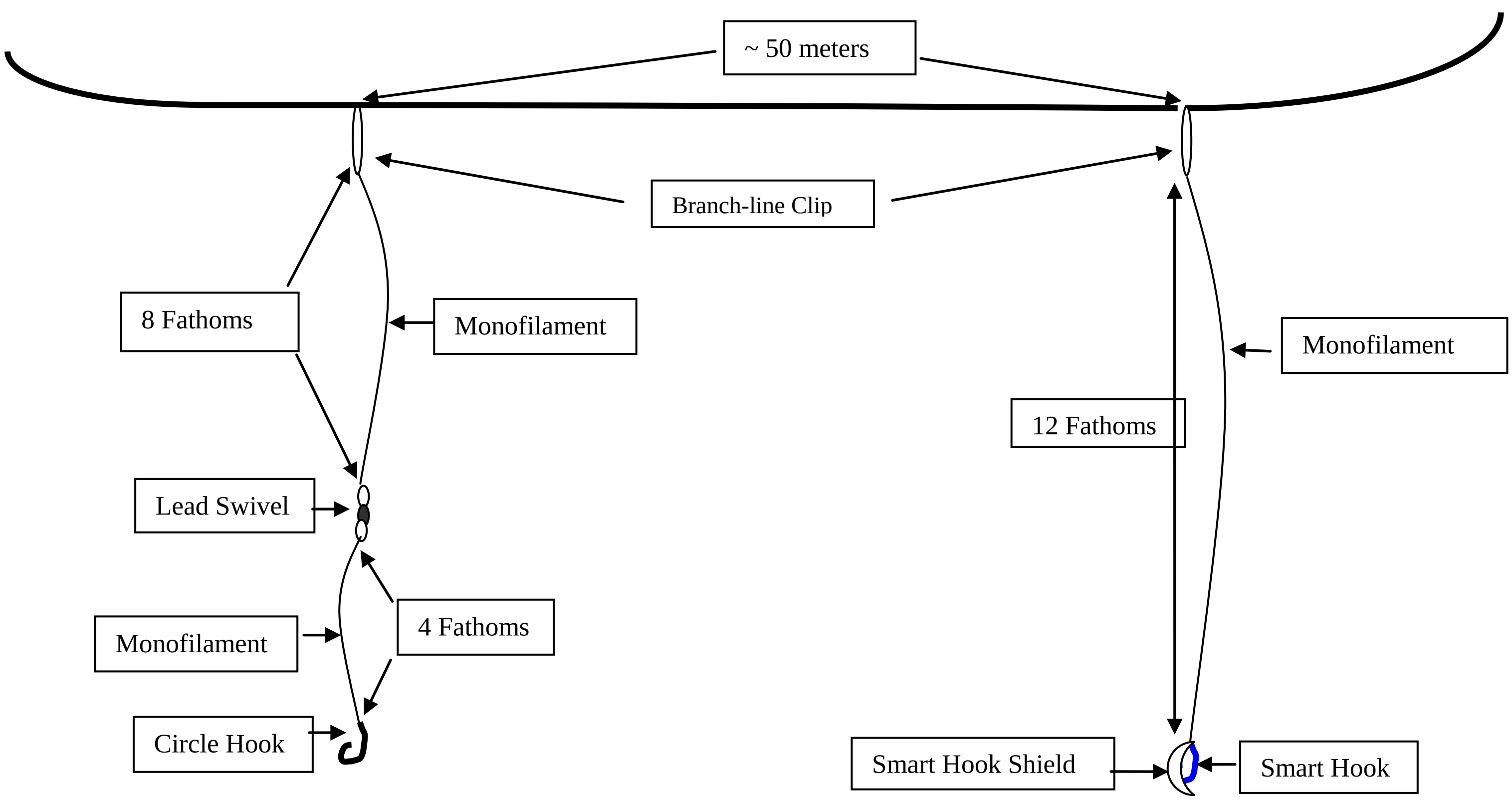
Bait used during the trial was sardines and squid. Squid was more prominent for night sets and was used in conjunctions with light sticks. When sardines were in use one or two sardines were placed on the hooks. Baits were typically 20cm in length.

Unchanged branch-lines (Figure 1) were 8 fathoms of monofilament from the branch-line clip to a lead swivel and 4 fathoms of monofilament from the lead swivel to a circle hook.

Branch-lines used for the Smart Hook had 12 fathoms of monofilament from the branch-line clip directly to the smart hook. The Smart Hook in this trial was a 3.8 Tuna Long-line hook with smart hook modification. i.e. a small bead strategically placed on the bend.

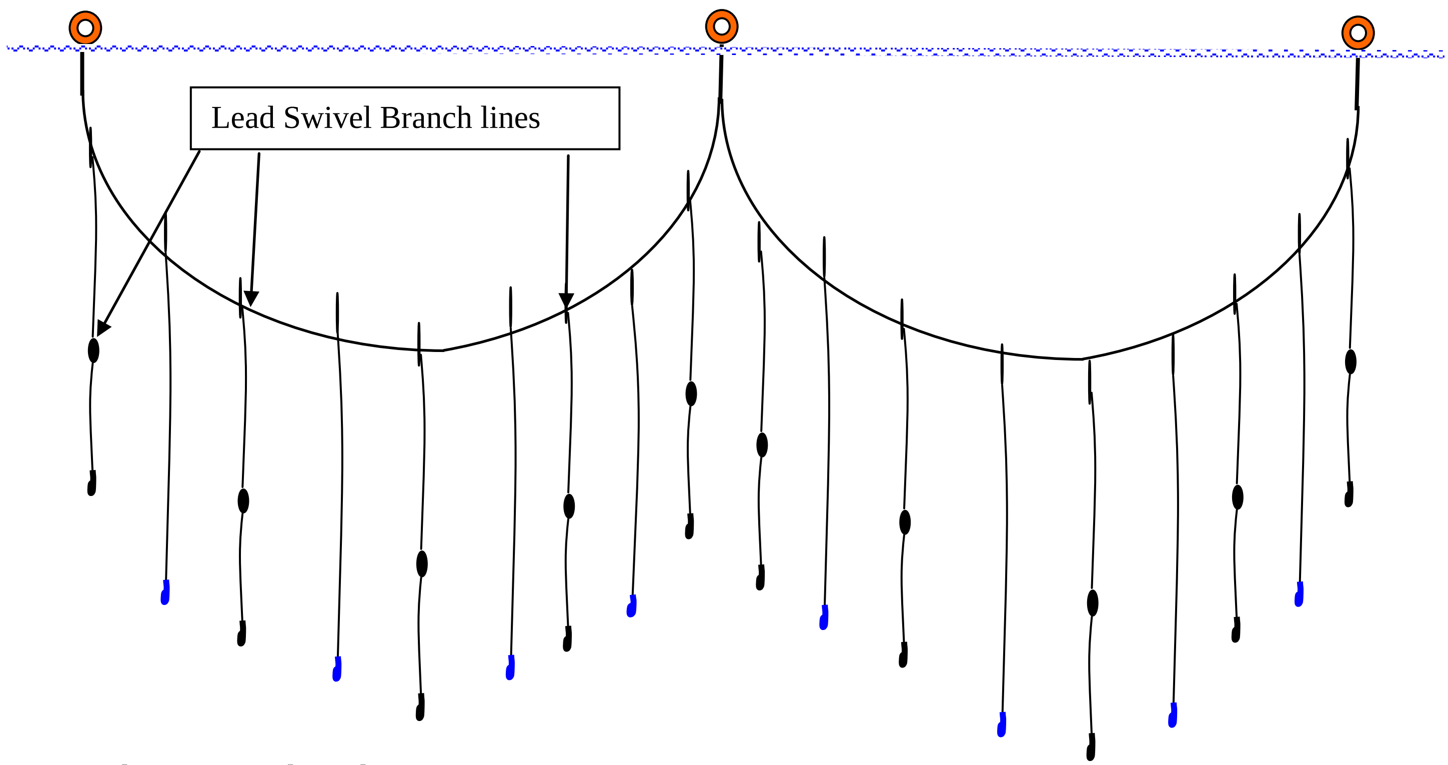
During daylight setting hours the Smart Hook shield was attached to all Smart Hooks.

Fig 1 Gear Configuration



Typically, eight or nine branch lines were attached to the mainline between floats (Figure 2). Floats were attached to the mainline with a separate 20-fathom line.

Fig 2 Mainline configuration



Setting & retrieval

Setting and retrieval was performed by all the crewmembers. Video footage was taken of all crewmembers setting the gear. Crew rotated the respective tasks from baiting, to clipping onto the mainline, to retrieving the branch-lines, making repairs and cleaning/processing the catch. This provided the opportunity for all members of the crew to try setting the fishing gear with the Smart Hook system in place.

Settings were undertaken both in daylight and night in varying weather conditions from relatively calm to choppy and rough. Setting was conducted into and with the wind, abeam to the prevailing weather and in the rain.

Setting was conducted at a vessel speed of 7 knots achieving approximately 250 hooks per hour. One crewmember baited the hooks whilst another crewmember clipped the branch-line onto the mainline and attached floats after 8-9 branch-lines.

The process for setting the gear using the Smart Hook system was to bait the Smart Hook with one or two sardines or a squid then attaching the Smart Hook Shield to the baited hook.

This was achieved by pushing the baited hook, barb first, into the cup of the shield and past the retaining clip. The baited hook was then cast outboard of the wash of the vessel.

The Smart Hook shields were kept in their original packaging, 250 per carton, on deck. The crew requested 20 -30 placed in a smaller container in the bait in for easy access and replaced as required.

At one point during setting the Smart Hook shields became soaked by a wave splashing over the deck. All the saturated shields continued being used without failure over the next 10 minutes.

The crew was also asked to tow a baited branch line, with the smart hook and shield attached, to determine if there was any twisting action of the line. The baited smart hook and shield were observed to tow as if it was a lead head lure/jig and tracked straight and true before being clip on the mainline.

Observations

Fishing operations

There did not appear to be any issues using the Smart Hook system on board the vessel, with the exception of changing the hooks to accommodate the shields. The Smart Hooks and shields were loaded onto the vessel along with other stores and kept in dry storage until required.

The inability to keep spare branch lines on board initially made it difficult to change over to the SHS and keep up with repairs. There was little time between sets to repair up to 25% of the branch-lines.
Repairs were conducted on an ongoing basis as the gear was being set to ensure a full set could be made.

The setting speed appeared to provide crew with time to conduct running repairs and maintain a consistent flow of the operations; the setting speed could be increased if repairs were completed prior to setting, this required a crewmember to undertake repairs rather than assist with the setting.

Setting

Fishing gear was set in all conditions including setting into the wind. The fishing gear was set after observing bird activity indicating fish, when feed layers were observed on the depth sounder and along temperature gradients.

Birds that were observed around the vessel and used as fishing indicators appeared to be White Faced Petrels, Black Petrels, Gannets and Frigate birds. There were no bird interactions what so ever with the fishing gear during the setting or hauling periods.

The crew was shown how the Smart Hook system functioned and how to attach the shield in an onboard demonstration.

The crew adapted quickly and easily to attaching the shield to the Smart Hook. The crew tried different ways of inserting the baited hook into the shield until they were comfortable with a particular method. Some crew tended to prefer inserting the hook with the hook and barb pointing away from them, whilst others were comfortable inserting with the hook and barb facing them.

The time to attach the shield was the same as attaching another bait to the hook; it did not increase the time taken to se the fishing gear or inhibit the operation.

Casting the bait

The crew commented that the baited Smart Hook with shield was easier to cast than an ordinary baited hook and branch line with a lead swivel. This was due to the double handling required with the lead swivel in the normal branch lines.

The crew felt the Smart Hook & shield assisted with retaining bait on the hook when casing and entering the water.

They also made comment on how quickly the baited hooked disappeared below the surface in comparison to the branch-line with swivel.

Retrieval

All fish that were brought aboard or discarded were observed. The type of hook used to capture the fish was recorded. There were no shields still attached t the hooks upon hauling the long-line.

Fish included the target species Yellowfin Tuna, Bigeye Tuna, Albacore as well as non-target species including, mahi mahi, sharks, spearfish, lancet fish, rudderfish. There were a number of tuna that had been shark bitten and were recorded as normal catch.

Damage to branch-lines was observed to be from breakage, bite off, damage from abrasion or nicks in the line near the hook, as a result of tangles or fish indiscriminately biting the line near the swivel or clip. The number of damaged branch-lines was not recorded.

Interviews

The captain and crew were all interviewed separately. The crew was asked identical questions. The following questions were asked, with the their general responses included.

The crew made general comment that they felt the smart hooks system was safer because it did not contain a dangerous lead swivel.

Questions for the Captain;

1. How long have you been Tuna Long-line fishing?
    a. 14 years
2. Is this the first time using the Smart Hook?
    a. Yes
3. Did the Smart Hook make setting difficult?
    a. No, hooks were spaced as normal.
4. Is the Smart Hook easy to include in your fishing operation?
    a. Yes, no different to putting a light stick on.
5. Would you be happy to include the Smart Hook in your fishing operations?
    a. Yes no worries.
6. Did you notice any changes to your catch with the Smart Hook?
    a. Seemed to catch the same amount of fish.
7. Do you have any suggestions for the Smart Hook?
    a. Packaging could be waterproof.

Questions for the Crew.

1. How long have you been Tuna Long-line fishing?
    a. 2-4 years
2. Is this the first time using the Smart Hook?
    a. Yes, first time seeing anything like it.
3. How have you found using it when setting the line?
    a. Easy, once you get used to it, basic, no trouble.
4. Did it take any more time to set?
    a. Not really.
5. Did it make any difference to setting or casting the bait?
    a. It helped casting the bait away from the vessel and keeping the bait on.
6. Would you be happy to use it in preventing the capture of seabirds & Turtles?
    a. Yes, definitely.
7. Do you have any suggestions for the Smart Hook system?
    a. Water proof cartons.

Data

Seven long-line sets over four days resulted in 3386 hooks being set. Three sets were after sunset where only the smart hook was included without the shield. Table 1 Setting Conditions and Table 2 Catch & Effort shows the data gathered on board.

Setting and retrieval data was confirmed with the Captain and crew to identify any discrepancies, none were found.

Data Analysis

The data in table 2, though a small data set, was used to determine any variations in catch. The following analysis graph table 3, is a comparison of the cpue.

Discussion

The indication of an increase in the CPUE, whilst derived from a small data set, warrants the Smart Hooks use on a larger scale. The increase in CPUE is believed to be due to

4. An increase in bait retention, resulting in fish having access to more baited hooks,
5. The bait reaching the target species quickly, whilst
6. Avoiding non-target species due to the increased sink rate.

Conclusion

The Smart Hook system was easily incorporated into the Tuna long-line fishing operations.

The Smart Hook system performed well under all conditions experienced as well as some not expected.

The Smart hook system can be easily included into Tuna long-line operations to mitigate the capture of seabirds and turtles.

Analysis of the data shows the Smart hook system increased the CPUE, increasing productivity and economic return.

Acknowledgements

The author acknowledges and gratefully thanks Bob Lamason and Great Barrier Reef Tuna for his support and in kind contribution to this project. FV Rummage Captain Cameron Keith and the crew members Madeline Fry, Kieran Prior and Ethati (Eddie) Hakai for their professionalism, suggestions and assistance in trying the Smart Hook system.

Table 1 Setting Sea Conditions

Set	Time	Wind Speed Knots	Sea Conditions	SST	Lat/Long	Set Direction
1	12:00	N 10	Calm	26.4	17s/147E	NNW
2	18:00	NNE 8	Calm	26	17s/147E	NNW
3	8:00	SSE 25	Choppy	26.2	17s/147E	N
4	19:00	Se 25	Choppy/Rough	26.3	17s/147E	SE
5	10:00	SE 25	Rough	26	17s/147E	NW
6	20:00	SE25	Choppy	25.8	17s/147E	W
7	17:00	SE 20	Choppy	25.4	17s/147E	NW

Table 2 Catch & Effort Data

Set #	Total Hooks Set	Smart Hooks set	Total Shields attached	Total # Fish Caught	Normal Hook catch	Species	# Smart Hook shield Caught Fish	Normal Hook CPUE	Smart Hook Shields CPUE	Smart hook Catch increase
1	500	50	50	6	6	Mahi	0			
2	486	50	0	25	23	YFT	0			
				28	25	BET	0			
				3	3	Mahi	0			
3	500	100	100	8	7	YFT	1			
				6	6	Mahi	0			
				1	1	SF	0			
4	500	100	0	5	4	YFT	0			
				3	2	BET	0			
5	400	150	150	11	9	YFT	2			
				1	1	BET	0			
				5	2	Mahi	3			
				1	0	SHARK	1			
				6	6	ALB	0			
6	500	150	0	10	7	YFT	0			
				2	2	BET	0			
7	500	150	150	15	6	YFT	9			
				10	6	BET	4			
				4	2	SHARK	2			
				1	1	RUD	0			
				1	1	SF	0			
TOTAL	3386	750	450	152	120		22	0.0443	0.0488	1.102
%		22.10%	13.29%		78.90%		14.47%			

Table 3 CPUE analysis