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AN EXAMINATION OF FAD-RELATED GEAR AND FISHING STRATEGIES USEFUL FOR DATA COLLECTION AND FAD-BASED MANAGEMENT

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1 Introduction

Purse seine fleets will continue to use FADs in their fishing operations as FADs provide them with all the benefits that FADs were designed to provide. Basically, FADs increase overall vessel efficiency by maximizing days at sea through a dramatic reduction in "zero catch" days, while minimizing searching time and allowing them (through improved technology to remotely monitor FADs) to maintain high annual landings per vessel. Another significant advantage of drifting FAD (DFAD) use is an increased ability to designate areas of operation through the seeding of DFADs in areas devoid of natural floating objects (FOs). Large arrays of anchored FADs (AFADs) have also been established in discrete areas of the WCPO that assist high production rates at known locations. AFADs in easily accessible coastal/archipelagic areas provide close fishing locations to smaller vessels that in many cases are not technologically geared to successfully exploit free schools of larger tuna.

The problems associated with intense FAD use are well known; i.e. heavy exploitation on small/juvenile size tuna, low market value, market flooding and price declines, higher bycatch, etc. Their impact on resource condition has suggested the possibility of implementing FAD-specific or gear driven restrictions as a management option to reduce fishing mortality on small and juvenile stage yellowfin and bigeye tuna. The problem is that most of the FAD specific technical information necessary to analyze FAD impact on catch has not been collected in a manner useful for analysis.

This paper will examine FAD design, fishing strategies and FAD-associated components that may be useful for research and management purposes. It is suggested that these components of FAD-based purse seining should be better documented for all WCPO purse seine fleets that utilize AFADs and DFADs. This type of information can not reliably be collected by vessel registries or in-port inspection. Currently, at-sea observer programmes are the best means to collect specific gear and operational characteristics of interest. Information Paper SWG-FT IP-4 to this meeting (SC3) provides a reference to the technical and operational information discussed here.

2 Summary of paper contents

This paper examines different gear and operational aspects of purse seine fishing on FADs from different perspectives. Information from fishermen from anecdotal sources and a paper examining the behaviour and experience of purse seine fishermen working on DFADs will be compared to scientific studies on the behaviour of tuna and influence of gear on bigeye catch. The current status of FAD-specific data collection in the Pacific will be reviewed followed by recommendations for data collection in the WCPO.

3 Information from the fishing industry

Purse seine fishermen have many opinions on the influence of FAD design and associated enhancements on attraction rates and other gear to increase catch. In some cases, opinions are inconsistent or conflicting but their opinions should be given due credit since their livelihoods depend on these matters. This section will attempt to list technical details and observations on FADs and associated gear from the fishing industry or from observations of gear and operational details.

3.1 AFAD design

Anchored FADs used to support purse seine and ringnet operations in the WCPO range from bamboo rafts to purpose-built steel platforms or cylinders (Itano et al. 2004). A streamlined shape, low current resistance and adequate flotation appear to be the primary considerations. Privately set anchored FADs in Hawaii have been constructed of rafts made of foam filled PVC pipes and floatation-filled, fiberglass enclosed boat hulls of about 5-6 m.

However, size has been noted to be a factor in some situations with very large floating structures, such as barges and vessels aggregating tuna very successfully, and at higher rates compared to conventionally sized FAD buoys within ten miles of the large FADs (Itano pers. obs.). Overall size for purse seining is a consideration when setting the net and during deployment that will likely maintain AFAD floats close to what are currently used. A consistent feature is that the streamlined design and bridling system to the mooring line allows AFADs to orient into the current and prevailing seas. Modifications to AFAD floats to incorporate devices or gear to attract tuna would be of interest but does not appear to currently be an issue.

3.2 DFAD design

Drifting FAD designs are also described in Itano et al. (2004) and reproduced in SC3 FT IP-4. DFAD floats are usually constructed of bamboo rafts or some combination of purse seine webbing and purse seine floats. Armsttong and Oliver (1994) interviewed US purse seine fishermen operating in the Eastern Pacific Ocean and utilizing DFADs. From an operational sense, the fishermen felt that compact DFADs and their ease of storage, deployment and recovery was more important than expending a great deal of effort on designing special features into the FAD structure. However, some DFADs were modified to hold chumming barrels thought to enhance the baitfish population around a DFAD.

Other fleets appear to favor bamboo rafts hung together with purse seine netting and floats (Morón, et al. 2001). The reasons for this are not clear but local availability of bamboo, good flotation to weight ratio and ample space on very large purse seine vessels are likely factors. Also, some of these fleets operate with FAD tender vessels dedicated to the construction, deployment and servicing of the fishing vessels which can dedicate deck space to FAD storage.

An interesting development in Indian Ocean DFAD technology has been the use of DFADs that have no surface float or raft at all (SC3 FT IP-4). These DFADs are constructed of carefully ballasted floats that suspend a long panel of purse seine neting that is weighted with surplus chain, purse cable or other scrap items. The entire FAD is suspended about 15 m below the surface and only marked with a GPS transmitting radio buoy and a few purse seine floats. These DFADs were developed to reduce the likelihood of discovery and poaching by other vessels.

3.3 Underwater appendages

Anchored FADs were first developed for large-scale fishery enhancement in the Philippines. Coconut fronds or other natural materials were always considered an integral part of Philippine payao construction with these materials hung from the AFAD float or suspended on separate weighted lines from the float (SC3 FT IP-4). This practice continues on the AFADs that are being set in Papua New Guinea and Indonesia by Philippine-based or Philippine-origin companies. **Figure 1** shows an aggregator line with several bundles of natural fiber suspended beneath an AFAD in Papua New Guinea. In other areas, plastic strapping, sections of poly rope and other materials have been added to AFADs though their effect has never been quantitatively proved.

Figure 1. Natural fiber aggregator suspended on a weighted line beneath an anchored FAD.

From available information, all WCPO purse seine fleets construct their drifting FADs in a similar manner with a considerable amount of sub-surface netting or other materials suspended beneath the DFAD float. These materials are weighted to hang vertically beneath the DFAD. Itano (1988) noted: “This generalized <DFAD> design varies from vessel to vessel, but there is a consensus among fishermen that a significant amount of subsurface area is important to a successful FAD.”

An extreme case of the importance of sub-surface mass to a drifting FAD was noted in section 3.2 where DFADs in the Indian Ocean are completely submerged with only a radio buoy at the surface (**Figure 2**).

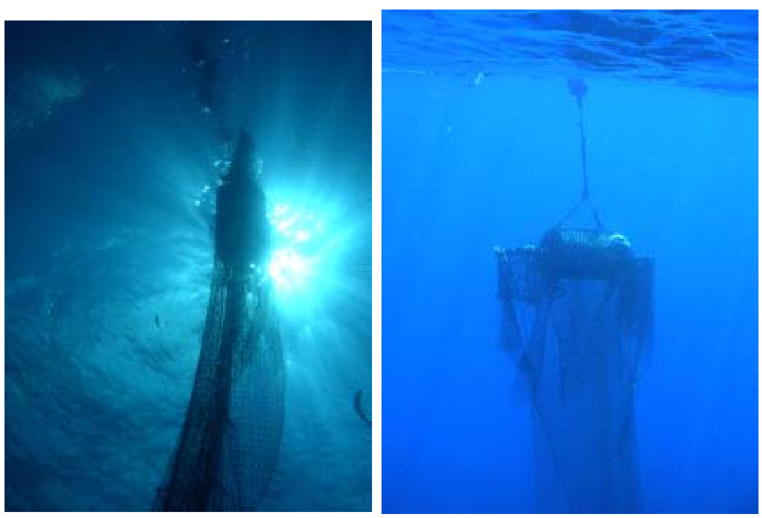

Figure 2. Sub-surface drifting FADs used to support purse seine operations (source FADIO).

3.4 FAD design enhancements

The use of chum barrels filled with fish oil was noted in the EPO by Armstrong and Oliver (1995) but its use in the WCPO has not yet been noted. The oil was thought to speed up the aggregation of small fish species making the FAD more attractive to tuna. Bait containers have also been used on EPO drifting FADs. Part of the motivation may be the observation by fishermen that some of the most productive

FADs have large communities of associated fish life and drifting whale carcasses can be very productive tuna FADs.

Kumoru (2002) reported on an experimental FAD design equipped with an underwater light for bait attraction in the PNG fishery. None of these FADs were seen during tuna tagging operations of the SPC/NFA PNG Tuna Tagging Project during 2006/07 and it is not believed that they are in use. However, underwater attraction lights have been used by many fleets for several years to enhance fishing operations on natural drifting objects and DFADs. However, the use of lights by fleet is not well understood in the scientific community.

3.5 Monitoring electronics

Purse seine fishermen acknowledge that advances in marine electronics and autonomous radio buoys has been the greatest enhancement to FAD fishing, and DFADs in particular. Concurrent advances in sonar, echo sounder and remote sensing equipment have also been critical in advancing catch rates on drifting FADs and floating objects in general. The technological developments have been documented in several reports and summarized in SC3 FT IP-4.

Figure 3 shows recent advancements in marine electronics that were specifically developed to assist purse seine vessels operating on drifting FADs. Sonar capable of marking the limit of the net after setting that indicate target depth, size, speed, direction and target strength are ideally suited for purse seine operations on FADs. The right panel shows a newer generation display for monitoring drifting FADs and assessing tuna abundance below the DFAD. Earlier models only prided a crude biomass estimate while this unit adds a higher definition display of fish below the unit comparable to the display of an echo sounder (note arrow pointing to fish target). These units operate on the Iridium satellite constellation and therefore have unlimited, worldwide range.

Figure 3. Figure 3. Advanced sonar for tuna purse seining and control system to remotely monitor tuna aggregation beneath a buoy-equipped drifting FAD.

3.6 Auxiliary vessels

Several vessel types other than the fishing vessel contribute to the efficiency of FAD directed purse seining that include towboats, echo sounder equipped small vessels, light boats, search boats and FAD tender vessels. FAD tenders or supply vessels are used in some fleets to deploy, recover, re-buoy, repair and monitor FAD aggregations. A primary function of these vessels is to search for any drifting object (including those belonging to other vessels), assess fish abundance and tie up to productive FADs to reserve its use for its associated catcher vessel Arrizabalaga et al. (2001). In many cases, the added efficiency caused by the use of FAD tender vessels has lead to the banning of their use.

3.7 Associated life

A common perception of purses seine fishermen is that productive floating objects tend to have a large biomass of other associated finfish aggregated to the object, such as oceanic triggerfish, rainbow runners, drummer and mackerel scad. This belief prompts some vessels to attempt to lead the associated fish out of the seine by slowly towing the floating object through a gap in the net close to the ship before beginning net retrieval (Bailey et al. 1994). Bait or chum containers have also been used in the EPO, apparently to foster the recruitment of non-tuna associated fish to the object.

3.8 General comments on FAD productivity

There is some consensus that a drifting FAD needs to be in the water at least a month before it will have aggregated enough tuna to allow harvesting. US purse seine captains interviewed by Armstrong and Oliver (1994) felt that the deployment location of a drifting FAD was the single most important factor to the productivity of a FAD and how quickly it aggregated fish tuna. For this reason, many fleets will seed DFADs upcurrent of productive waters or leave FADs to "season" between trips or to be made available to cooperating vessels.

4 Studies on Fishermens Behaviour – Local Ecological Knowledge

A recent study by Moreno et al. (2007 in press and **SC3-FT-WP-5**) examined the knowledge and experience of purse seine fishermen in the Indian Ocean on tuna behaviour in relation to drifting FADs. The study conducted structured personal interviews with the primary fishing captains of all European Union (French and Spanish) purse seine vessels operating in the western Indian Ocean. The interviews concentrated on fishermen's perspective of the behaviour of tropical tuna aggregated to drifting FADs. Only the information relevant to FAD efficiency and influences on FAD aggregation will be noted here.

The captains noted that it was rare to find tuna aggregations on a DFAD without a good aggregation of non-tuna species, such as the rainbow runner, triggerfish and silky shark. The majority believed that DFADs had an attraction distance of 2 to 5 nautical miles and that natural drift logs were generally more productive than DFADs. However, 32% of the respondents believed that there was no discernable difference between logs and man-made FADs in their ability to aggregate tuna. The majority (54%) felt that non-tuna began aggregating to their DFADs one week after deployment while most of all captains felt that non-tuna species would arrive within 1-4 weeks.

Replies on the time required for tuna aggregation were more variable. Most captains stated that the time required for tuna aggregation was subject to many environmental and abundance factors and could not be simply predicted. However, 36% of captains suggested that a minimum of one month was required for a DFAD to aggregate a good school of tuna. Unfortunately, specific information on FAD design or gear modifications was not investigated.

5 Analyses of FADs on behaviour and gear effects on catch

(i) Harley et al. (2004) and Maunder (2006) examined the possibility of bigeye vessel catch limits or trip limits as a mechanism for reducing bigeye fishing mortality in the EPO. During 1999-2005, between 11 and 15 vessels captured 50% of the bigeye catch, but only about 5% of the yellowfin catch and 18-32% of the skipjack catch. This number of vessels represents a small proportion of total effort suggesting that some higher catch rates of bigeye may be driven by gear or operational factors.

(ii) Langley (2004) examined factors that may influence bigeye catch in floating object sets. Unfortunately, only data from the US fleet operating in the eastern area of the fishery was adequate in spatio-temporal characteristics to allow the analysis. Among other findings, the study determined that:

(a) Bigeye catches peaked during new moon and were lowest during full moon.

(b) bigeye catches on DFADs were slightly higher overall than from natural drifting logs, and

(c) there was a high variability in bigeye catch between individual vessels (on drifting object sets) with some vessels having considerably higher catch rates of bigeye.

The observation that bigeye catches peaked during new moon relates to independent data from archival tagging on drifting FADs that bigeye tend to occupy deeper water during full moon periods (Schaefer and Fuller 2005). Other archival studies have supported the deeper diving tendency of bigeye during full moon periods (Musyl et al. 20003).

The high variability in bigey catch between vessels, with a few boats achieving much higher catch rates of bigeye are similar to the IATTC studies, suggesting the possibility of technical factors that contribute to bigeye catch on floating objects. The observation that drifting FADs had higher catch rates of bigeye compared to natural drift logs also suggests the possibility that some factor to DFAD design or use may positively influence bigeye aggregation.

Unfortunately, follow up studies to examine possible differences in FAD construction, fishing gear, and fishing strategies were not conducted in the WCPO. Apparently, the technical parameters necessary to evaluate these differences have not been collected in a systematic manner in the WCPO to allow such analyses. However, an analysis by the IATTC on gear effects and bigeye catch is described below.

(iii) Lennert-Cody et al. (2007 and **SC3-FT-IP-1**) developed a classification algorithm to examine gear influence on bigeye catch by EPO purse seine vessels. Several gear and operational parameters were examined, i.e. vessel capacity, net depth, mesh size, FAD depth, degree of FAD bio fouling (barnacles, etc), set time, location, SST, SST frontal zones, bathymetry, productivity, oceanographic parameters and the presence of non-tuna species. FAD depth refers to the maximum depth of the netting aggregator hanging beneath the FAD float.

Of the gear characteristics examined, the depth of the FAD and the hanging depth of the purse seine net had the greatest positive effect on bigeye catch, but geographic location within the EPO had the greatest overall influence on bigeye catch. However, previous studies provided some indication that skipjack catch per set also increases with increasing net depth (Lennert-Cody and Hall 2000), thus restricting net depth may reduce skipjack catches unfairly. This is not surprising and would be much more influential in the WCPO with a deeper thermocline and better underwater visibility. Under these conditions, very deep nets are necessary in order to successfully target unassociated schools during the day (Doulman 1987). Another problem of analysis of net depth is that reported hanging depth of the net was used as a proxy for actual fishing depth which can vary widely depending on currents and pursing speed.

An interesting result of the analysis indicated some vessels that caught bigeye when none were predicted. The authors suggest this may indicate some type of vessel effect that should be further investigated.

6 FAD data collection by observer programmes

6.1 IATTC Observer Program

IATTC observers on EPO purse seiners fill in a specific form that describes floating objects that are set or investigated. A copy of the FLOTSAM INFORMATION RECORD (FIR) is attached as **Appendix I**. Observers complete a separate form to describe any of these situations:

a) When an object is placed in the water for the first time ('deployed');
b) When the vessel stops to investigate a floating object;
c) When the vessel returns to a previously sighted floating object;
d) When a floating object is taken aboard the vessel;
e) Any time a set is made on a floating object (LOGSET).

The form is used for all types of floating objects that can aggregate fish, including natural vegetation, manmade rubbish, drifting FADs and floating dead animals. The form also records details of associated locating gear (flag markers, lights, radio buoys, radar reflectors, etc.), hanging netting, bait containers, entrapped fauna, maximum depth, % of bio fouling and ownership. The technical capabilities of radio buoys are noted as well as method of location and total dimensions of the FAD float and depth/dimensions of the subsurface netting. It is significant to note that the form has specific columns to describe the item as it was found vs separate columns to describe how it was left. For example a natural tree may be found but when it is left it may have netting, floats, a radio buoy and lights attached. The log would at this point be classified as a drifting FAD rather than a natural log. The second and third pages provide space for a drawing of the object and additional notes.

The tracking and identity of a drifting FAD can be very problematic, with DFADs taken onboard, modified, and in some cases appropriated from other vessels and provided with a different radio buoy. The IATTC has dealt with DFAD identification in the following manner (from Instructions to FIR):

> "A very important feature of the FIR is that it enables an object to be tracked throughout a trip, by means of the Object No. and Count No. recorded in the form header. When an object is sighted for the first time during a trip, it is assigned a unique number, the Object No., which is used for that object throughout the trip (except in the one case described in the following paragraph); the Count No. is a sequential number used to track each visit to a particular object during the trip.
>
> If an object is taken aboard the vessel and is later returned to the water while the vessel is still drifting (*i.e.* there is no change in the event on the *Daily Activity Record*), the object keeps the same Object No. and the sequence of Count No is continued. In this case, it is assumed that the vessel takes the place of the object when it is taken aboard and, as long as the vessel remains drifting, the 'habitat' is maintained, and when the object is returned to the water, it is reunited with the same fauna. However, if an object is taken aboard and the vessel then leaves the area (*i.e.* you record a SEARCH or RUN event on the *Daily Activity Record*) before the object is returned to the water, the object is assigned a new Object No. In this case, the object is considered to have been removed from its original 'habitat' and separated from its accompanying fauna, and thus becomes a 'new' object for the purposes of the FIR."

6.2 SPC/FFA Regional Observer Programme

The SPC/FFA regional observer forms capture some of the same information but the programme does not have a specific form for flotsam or FAD details. The PS-1 form contains fields to describe marine electronics, radio buoy types and particulars of the vessel, auxiliary boats, deck machinery, net and brailer. The PS-2 form requires a simple tally of anchored or drifting floating objects with or without schools present. School association codes categorize every sighting as to drifting object type and activity codes describe events such as: investigate floating object, deploy FAD, retrieve FAD or change radio buoy.

Other details of FAD use are described in free text fields of the SPC/FFA Regional Observer PURSE SEINE TRIP REPORT. Section 4.4 requests additional information on marine electronics and to note new electronic gear. Section 4.6 asks the observer to record any new or innovative gear or equipment.

Section 5.1 has three separate sections for the observer to describe FADs, natural drift objects and animal associations (dead or alive). These sections provide a limited space to describe all the FADs and floating objects encountered during the entire trip and are inconsistent between sections. The FAD section asks the observer to describe the FAD types, hanging appendages or aggregators, FAD deployments, setting procedures and the role of buoy electronics and sonar during the trip. Observers are specifically asked if lights or bait containers are used with the FADs. For natural logs, the amount of baitfish and the ownership of the log/radio buoy is requested. The same information is not asked of drifting FADs.

7 Recommendations for data collection of FAD-related gear

The basic question is "what makes a floating object attractive to tuna, and how might these factors be used to assist management goals"? For anchored FADs, location is obviously the main consideration with current regime, water quality, mooring depth, proximity to islands and abundant tuna resources playing important roles. Additional factors that may increase aggregation will be generally in common with drifting FADs and discussed below.

For data collection on drifting FADs, the IATTC FLOTSAM INFORMATION RECORD provides a good starting point for discussion as it contains the key points to consider in describing and tracking floating objects. The form provides basic identification parameters across the top including time of set and information to track the floating object. The rest of the form categorizes the FO components, associated electronics, how FO located, netting/appendage description, FO dimensions and information on the origin or ownership of the FO. Of importance, the form describes the FO when found and separately describes it "when left" as significant alterations/enhancements may have been made.

Currently, the SPC/FFA Regional Observer forms do not accurately describe individual floating objects, including interesting parameters for study such as underwater structure, dimensions, use of lights, chumming, ownership and origin of the DFAD. Information on many FAD details is requested in written form in the Purse Seine Trip Report, but the observer is asked to reply to several questions and summarize answers for all floating objects that were visited during the entire trip. Details on different types of DFADs or associated gear would be difficult to glean from these summaries. The main issue is that this sort of information in written form is difficult and time consuming to review and summarize and difficult or not useful for analysis.

Past studies in both the EPO and WCPO have indicated interesting heterogeneity in bigeye catch from purse seine fisheries. In some cases, a relatively small number of vessels land a disproportionately high percentage of bigeye in floating object sets. Analysis of these vessels has not been possible in the WCPO as FAD-specific data is not available. FAD issues and the need for effort management on floating object directed fishing will continue, suggesting that a better system to collect FAD specific data should be instituted.

Means to verify and record the actual fishing depth of the nets should also be adopted by regional observer programmes. Net sonde gear, archival tags and depth sounders in the DFAD towboats are possible ways to obtain this information. However, obtaining this information may require a closer working relationship between industry and science. The accumulated knowledge of WCPO purse seine fishermen should be better utilized and incorporated into developing workable options for reducing the take of small tuna on floating object sets. Collaboration between fishermen and scientists during the planning stages of research invests the industry in the process and can help scientists avoid costly and time consuming mistakes.

8 References

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9 Appendix I. IATTC FLOTSAM INFORMATION RECORD

Inter-American Tropical Tuna Commission
FLOTSAM INFORMATION RECORD (FIR)

Trip Number	Object No.	Count No.	Set No.	DATE YY MM DD	TIME	LATITUDE N/S	LONGITUDE

A. COMPONENTS (check all that are applicable)

Tree	[ ]	1	[ ]
Dead animal	[ ]	2	[ ]
Chain / cable / rings / weights	[ ]	3	[ ]
Cane / bamboo	[ ]	4	[ ]
Bait container / bait	[ ]	5	[ ]
Cord / rope	[ ]	6	[ ]
Floats / corks	[ ]	7	[ ]
Artificial light for attracting fish	[ ]	8	[ ]
Netting material	[ ]	9	[ ]
Sacks / bags	[ ]	10	[ ]
Planks / pallets / plywood /	[ ]	11	[ ]
Metal drum / plastic drum	[ ]	12	[ ]
PVC or other plastic tubes	[ ]	13	[ ]
Plastic sheeting	[ ]	14	[ ]
Unknown	[ ]	15	[ ]
Other	[ ]	16	[ ]

B. LOCATING EQUIPMENT (check all that are applicable)

Flag	[ ]	1	[ ]
Satellite buoy	[ ]	2	[ ]
Buoy, corks, etc.	[ ]	3	[ ]
Lights	[ ]	4	[ ]
Radio transmitter / beeper	[ ]	5	[ ]
Radar reflector	[ ]	6	[ ]
Unknown	[ ]	7	[ ]
Other	[ ]	8	[ ]

C. LOCATING METHOD (check only ONE)

Radar	[ ]	1	
Direction finder	[ ]	2	
Satellite	[ ]	3	**check**
Visual – the object itself	[ ]	4	**only**
Visual – birds	[ ]	5	**one**
Not applicable	[ ]	6	
Unknown	[ ]	7	
Other ______________	[ ]	8	

D. IF THERE IS NETTING ON THE OBJECT:

	Yes	No	Unk
Netting hanging from the object?	[ ]	[ ]	[ ]

Estimated area of hanging ______

Predominant mesh size (inches) ___.___

E. OTHER DATA

	Yes	No	NA	Unk
Bait container refilled?	[ ]	[ ]	[ ]	[ ]
Fauna entrapped?______________	[ ]	[ ]	[ ]	[ ]

Maximum depth of the object (m) ______

Dimensions (m) ______ ______ ______

Water clarity **Clear** [ ] **Turbid** [ ] **Very turbid** [ ]

% epibiota ______ Tag number ______

F. CAPABILITY OF TRANSMITTING EQUIPMENT (check

	As found		As left
Direction to the object	[ ]	1	[ ]
Geographic position of the object	[ ]	2	[ ]
Water temperature	[ ]	3	[ ]
Tuna quantity	[ ]	4	[ ]
Tuna species	[ ]	5	[ ]
Unknown	[ ]	6	[ ]
Other	[ ]	7	[ ]

G. PRIOR ORIGIN OF OBJECT (check only ONE)

Your vessel – this trip	[ ]	1	
Your vessel – previous trip	[ ]	2	
Deployed	[ ]	3	
Other vessel – with owner consent	[ ]	4	**check**
Other vessel – no owner consent	[ ]	5	**only**
Drifting object found	[ ]	6	**one**
Unknown	[ ]	7	
Other ______________	[ ]	8	

H. EXPERIMENTAL EQUIPMENT (continue on back)

I.a. OVERHEAD VIEW (Include dimensions)

I.b. SIDE VIEW (Include dimensions)

J. ADDITIONAL COMMENTS