Proceedings of the Workshop on At-sea Detection and Removal of Derelict Fishing Gear

Honolulu, HI
December 9-10, 2008

Kris McElwee and Carey Morishige (eds.)

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Ocean Service
Office of Response and Restoration
Marine Debris Division

National Oceanic and Atmospheric Administration
Technical Memorandum NOS-OR&R-34
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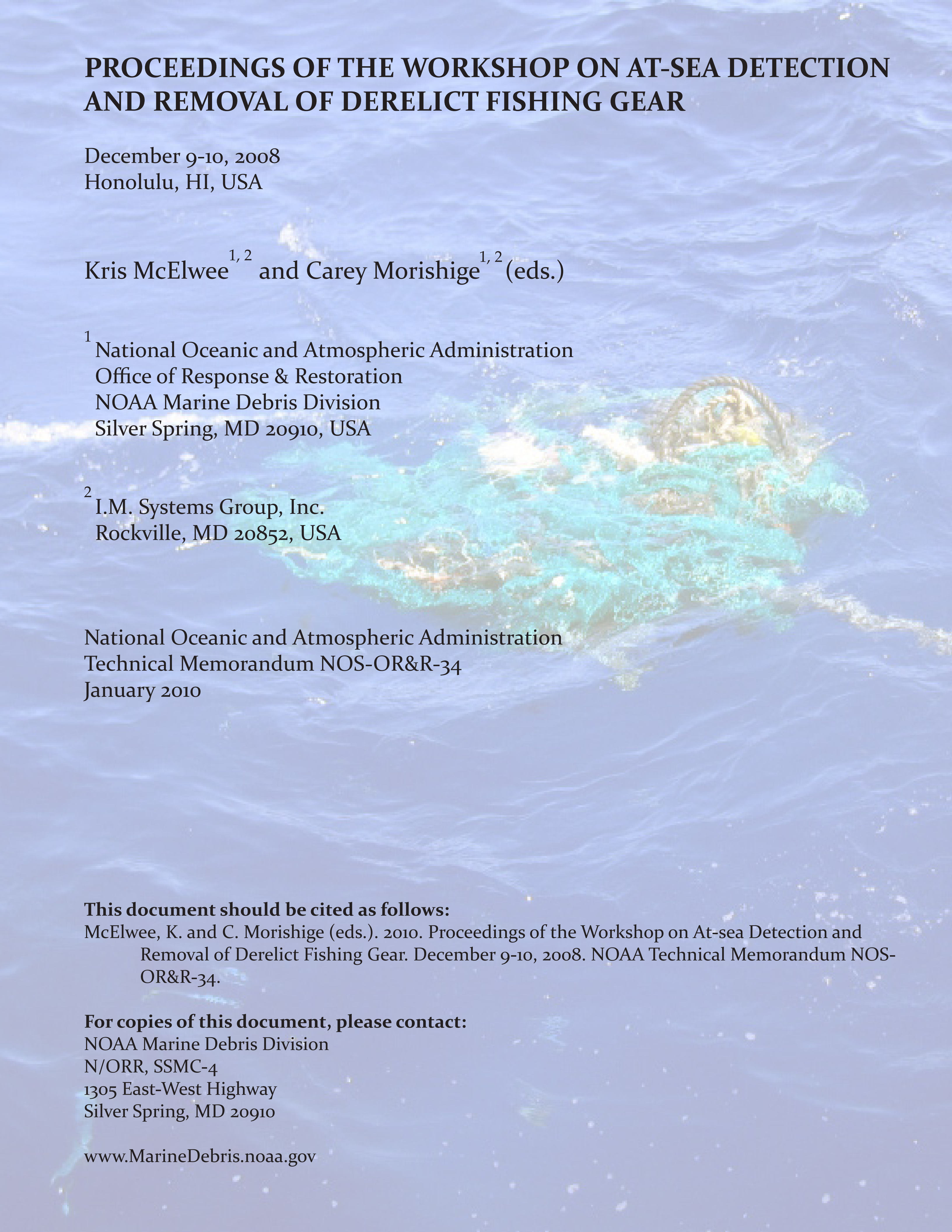

PROCEEDINGS OF THE WORKSHOP ON AT-SEA DETECTION AND REMOVAL OF DERELICT FISHING GEAR

December 9-10, 2008
Honolulu, HI, USA

Kris McElwee[1, 2] and Carey Morishige[1, 2] (eds.)

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Background

Derelict fishing gear (DFG) is a threat to marine ecosystems, posing entanglement hazards for marine life, smothering the living substrate upon which it settles, and in at least one case to date serving as a vector for the introduction of alien species (Zabin et al., 2003). Across the Pacific, DFG is now recognized as a major environmental threat to coastal and nearshore areas. A regional "hotspot" for DFG is the Hawaiian Archipelago, particularly the Northwestern Hawaiian Islands, due to their proximity to the North Pacific Subtropical Convergence Zone, an area where ocean currents accumulate DFG from the North Pacific Ocean (Figure 1).

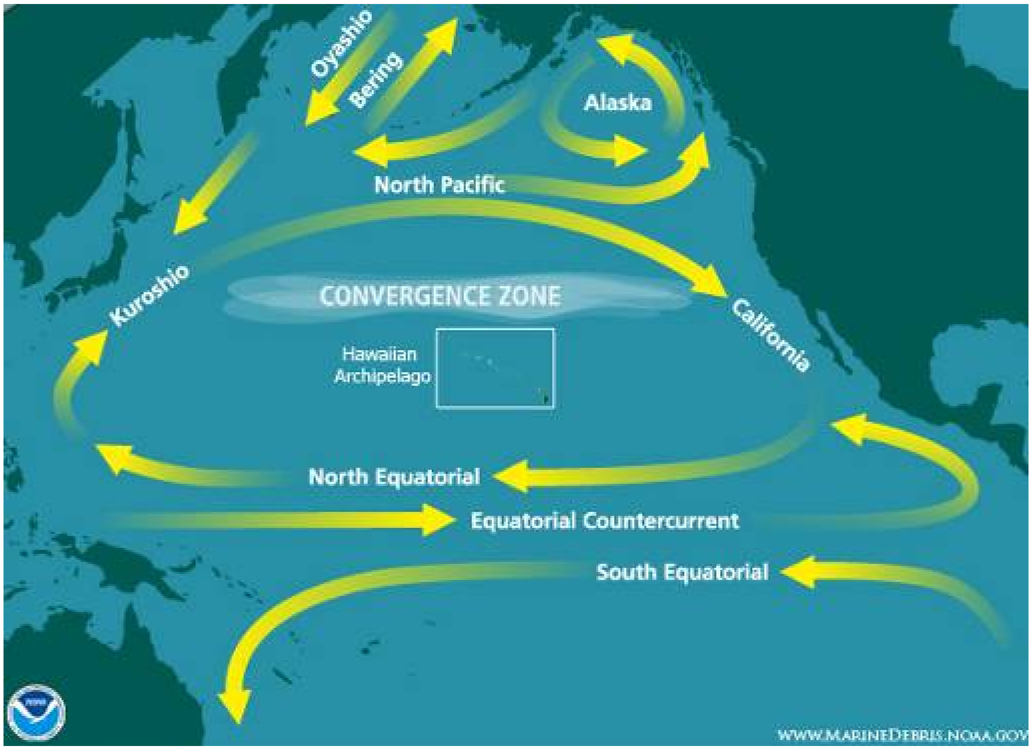

Figure 1. Location of the Hawaiian Archipelago relative to the main Pacific Ocean currents and the North Pacific Subtropical Convergence Zone.

In response to the threat posed by DFG, NOAA and USCG have conducted an 11-year DFG removal effort in the waters of the Northwestern Hawaiian Islands, collecting 635 metric tons to date. These efforts were scaled back in 2006 and 2007 to target the approximately 18 metric tons of DFG then estimated to accumulate annually (Figure 2). However, this deposition rate has recently been revised, indicating that more than 50 metric tons of DFG is becoming entangled in the natural resources of the Papahānaumokuākea Marine National Monument each year (Dameron et al., 2007). This revised deposition rate, the sensitive species at risk from DFG, and the high cost of removing DFG from aquatic environments warrants the exploration of removal efforts targeting DFG at sea, prior to its contact with these sensitive habitats.

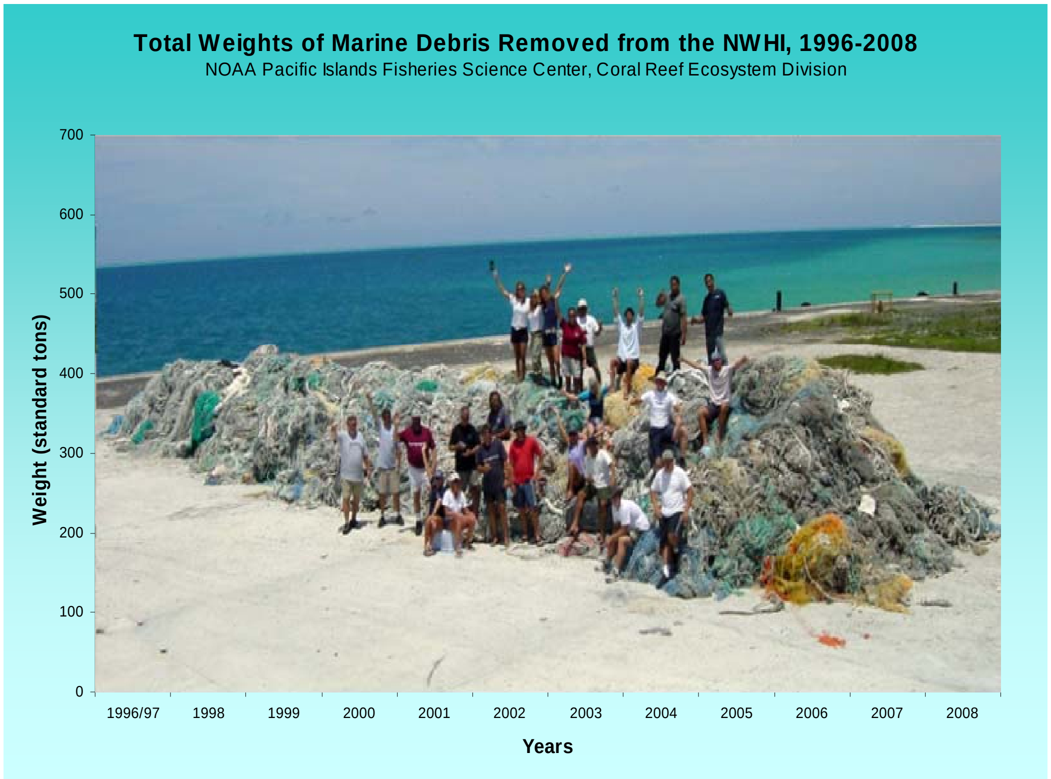

Figure 2. Annual and cumulative weight of marine debris removed from the Northwestern Hawaiian Islands 1996-2008 (through Sept. 29, 2008).

Two potential uses of an at-sea detection capability are: 1) seeking solutions to locating debris for removal, and; 2) conducting a census of marine debris to assess the scale of the problem and determine the fraction of DFG that enters shallow-water sensitive environments. The appropriate management action is likely to be different if very little (e.g., <1%) or a large amount (>20%) of the DFG at sea enters shallow-water environments annually.

Recent research suggests that DFG concentrations can be modeled, which would substantially reduce the search area and improve efficiency of detection (Kubota, 1994; Pichel et al., 2003). Manned flights over the North Pacific Subtropical Convergence Zone in 2005 confirmed these model predictions, identifying 122 pieces of DFG (Pichel et al., 2007). The potential exists for large amounts of DFG to be located and removed at sea. A 2008 pilot project to conduct such an effort revealed the following areas in which additional work was needed:

- Enhanced coordination and mutual understanding among scientists and technology experts regarding project planning, goals, and implementation
- Enhanced understanding of at-sea debris movement rates relative to the rate of movement of the Transition Zone Chlorophyll Front and its proxy, the 18°C sea surface isotherm

- Capability to launch, fly, and recover an unmanned aircraft system (UAS) in up to 25-knot winds and associated sea states
- The development of a UAS with autonomous flight capabilities
- Selection of an ideal sensor type and quality
- Testing of anomaly detection software on DFG in various sea states

If feasible, a preemptive at-sea detection and removal strategy would achieve several major successes concurrently:

- Proactive prevention of DFG-induced damage to the species and habitats of Hawaii and other affected areas on the Pacific Rim
- Immediate reduction of the DFG threat to pelagic species and habitats
- Reduction of the DFG threat to coastal and insular species and habitats throughout the affected areas on the Pacific Rim and Hawaii
- More effective allocation of marine debris funding by addressing the DFG problem closer to the source

Workshop Structure

A summit of NOAA, other federal agency, and private sector experts in marine debris, oceanography, biology, and remote sensing technology was held to identify existing knowledge, gaps in understanding, and actions that can be taken to allow progress toward at-sea detection and removal of derelict fishing gear.

Workshop objectives:

- Development of an action strategy through government and private sector expertise to research, develop, and test technologies and protocols to assess the amount of DFG in the North Pacific and ultimately detect and remove DFG from the pelagic environment before it reaches sensitive nearshore environments.
- Identification and synthesis of existing information on the behavior and movement of marine debris in the North Pacific; appropriate sensor, UAS, and anomaly detection technologies; and activities that have been undertaken to date to detect and track derelict fishing gear.

Given the wide variety in expertise and experience of workshop participants and the limited time available for the meeting, it was determined that a method to share the essentials of the state of our knowledge was necessary. To accomplish this preparation, 17 informal background papers were prepared by workshop participants with information on their area of expertise pertaining to the at-sea detection and removal of marine debris. Papers were solicited in three broad subject-matter areas: 1) marine debris, 2) oceanography, and 3) technology (see Appendix I, table of contents from the collection of background papers). Each paper was written following the template below:

Introduction – Brief description and history of the topic, including terminology used. What is the importance of this topic in addressing marine debris issues?

What's Known?– What are we certain about? What information and data do we have?

What's Very Likely? – What are we fairly certain about? What information and data will help us be more certain?

What's Not Certain? – What are we unsure about? What don't we know? What information and data are missing?

What is Needed? – What early actions (1–2 years) are needed? What mid-term actions (2–5 years) are needed? What longer-term actions (>5 years) are needed?

Figures and Tables

References

The collection of background papers was distributed to participants one week before the meeting.

The two-day workshop was held December 9–10, 2008 in Honolulu, Hawaii, at the Waikiki Beach Marriott Resort and Spa (see Appendix II, agenda, and Appendix III, participants). The first day was spent reviewing the state of knowledge in the three subject-matter areas of 1) marine debris, 2) oceanography, and 3) technology. Brief presentations on various aspects of each subject-matter area pertaining to the at-sea detection and removal of derelict fishing gear were given by experts in the field (Appendix IV). Each presentation discussed the four questions:

1. What is known?
2. What is very likely?
3. What is not certain?
4. What is needed?

Additional information on the state of knowledge based on the experiences of the participants was also shared and discussed during presentations. A bulleted summary of the discussions is presented in Appendix V.

The afternoon of the first day was spent identifying and discussing gaps in knowledge that limit our capability to detect marine debris at sea. A gap-mapping activity was conducted in four breakout groups comprising a mix of individuals from the three subject-matter areas. A summary table of all gaps identified within the background papers was used as a resource during this activity (Appendix VI). Within each group, participants took numbered gap cards (one gap per index card) and grouped them by commonality. Once done, each group of similar or related gaps ("gap theme") was reviewed, discussed, and rearranged as needed by all members of the breakout group. The overall objective of this activity was to familiarize all workshop participants with the identified gaps in knowledge and then to define linkages between those gaps.

The second day of the workshop was spent working in the previous day's integrated breakout groups and in subject-matter expert groups to begin to build out the connections between gaps and identify the various items (activities, pieces of knowledge, etc.) needed to address those gaps and to take us one step closer to the at-sea detection and removal of derelict fishing gear.

To do this, the day began with a storyboard-creating activity. Members worked in their original breakout groups to review the results of the previous day's gap-mapping activity. Groups were asked to develop a primary question that needed to be answered in order to detect derelict fishing gear at sea. Once that question (or questions) was identified, groups then began identifying sub-questions and "gap themes" related to these questions. They also worked to define linkages between gap themes as well as additional gaps that weren't identified in the background papers. In a step-wise or storyboard fashion, groups then worked to identify strategic actions needed to address particular gaps or gap themes. At the end of the activity each group had created several strategic storyboards to help answer their main question(s) (Appendix VII).

During a break, all participants had an opportunity to browse and review the other groups' strategic storyboards. This was followed by presentations explaining each group's storyboards and thought process.

The afternoon of the second day was used to build upon the storyboard activity by beginning to flesh out those strategic actions that would help improve our capability to detect and remove marine debris at sea. Participants were grouped, this time, by area of expertise: 1) marine debris, 2) oceanography, and 3) technology. The actions outlined on each storyboard were distributed by subject matter to the appropriate group. Based on what they had seen and learned throughout the workshop thus far, participants worked together to capture some details on the strategic actions and activities in their area of expertise. For each strategic action, a template was filled out with the following information:

- Action needed (short title)
- What gap does this action address, and how? How does this gap relate to marine debris?
- What are steps to carrying out this action?
- What organizations and individuals need to be involved, and how?
- Who has the technology, expertise, resources, and materials to carry this out?
- What are the impediments to overcome to carry out this action?
- Are there other (non-marine debris) benefits to this action?

The strategic actions are grouped by theme in Appendix VIII, and the strategic action templates are summarized in Appendix IX.

The workshop ended with a discussion of some of the immediate actions needed to begin effectively addressing the at-sea detection and removal of marine debris. Additionally, participants engaged in a discussion on continued future collaborations and the immediate next steps moving forward from this workshop.

Strategy

In an attempt to distill the common elements of the strategies developed by each breakout group, we have created an overall strategy. The storyboards that each breakout group developed (Appendix VII) were combined into this overall strategy, focused specifically on detecting derelict fishing gear at sea (Fig. 3). Other related objectives, while important to the overall goal of understanding and decreasing marine debris, were not included in this strategy. The goal of the overall strategy is to develop the capability for detection of derelict fishing gear at sea. Needed actions fall under four main areas (sub-strategies): characteristics and behavior of derelict fishing gear, characteristics of the operational environment, modeling of derelict fishing gear location, and direct detection of derelict fishing gear. Some of the actions are sequential; others can proceed simultaneously or independently.

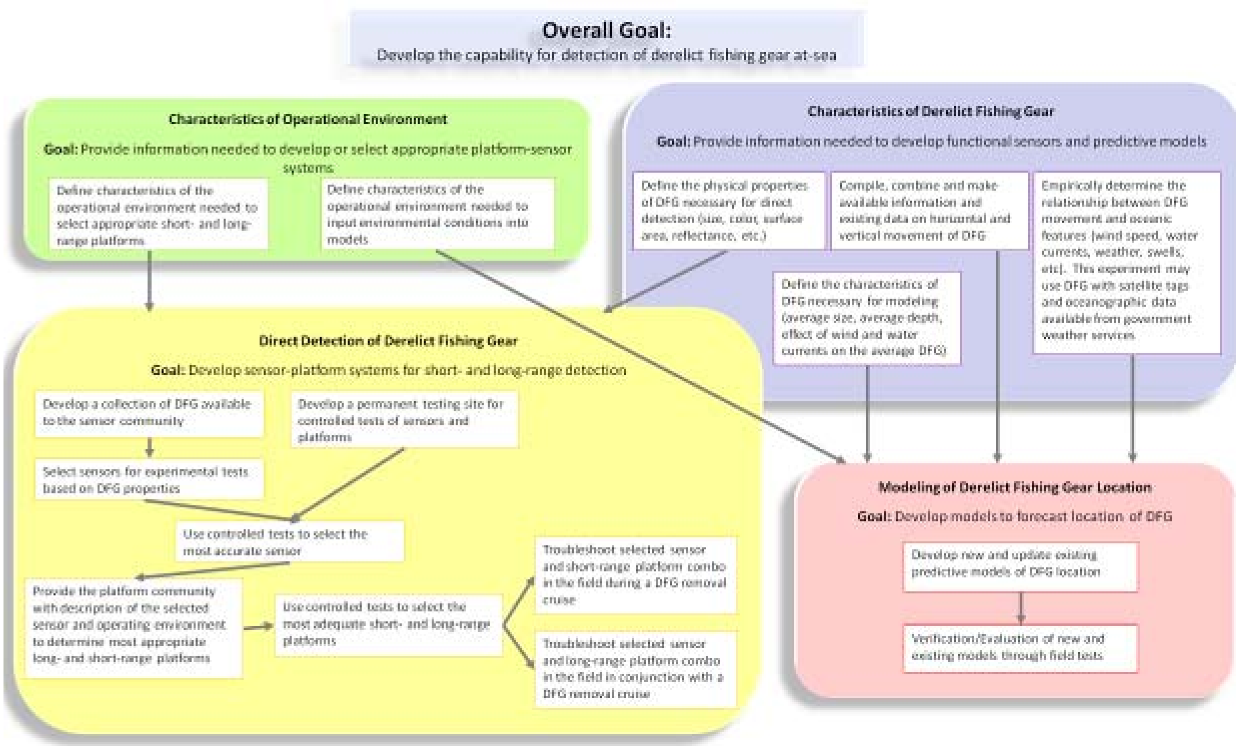

Figure 3. Combined strategy map on the detection of derelict fishing gear.

Characteristics and Behavior of DFG

The goal of this sub-strategy is to provide information needed to develop functional sensors and predictive models. Compiling existing information and addressing critical gaps in understanding of the characteristics of DFG, as well as those of the operational environment (see next section), are the basis for developing appropriate sensor-platform systems and predictive models. The remote sensing experts stressed that the first step in building a requirements document is understanding the nature of the "target." The oceanographers also need to understand the characteristics of the item being modeled, because various objects are acted upon differently by wind and currents depending on their size, vertical profile, and buoyancy. The type of material, size, concentration of encrusting organisms, and other factors determine the optical properties, buoyancy, and movement patterns of DFG. An understanding of the optical properties and movement patterns of DFG is needed in order to assess the utility of various sensors and develop accurate models, respectively. Because most observations of derelict fishing gear have been anecdotal, and data have not been gathered on nets' size, composition, and changes over time, several actions were suggested to fill this gap.

One proposed step was collecting a variety of DFG samples from the open ocean for testing with sensors. While DFG is collected off reefs in the NWHI every year, those samples may be significantly altered by wave action during their passage over the forereef; samples of DFG found onshore may also be unlike open-water samples. Understanding the orientation of gear in the water was also identified as important both for modeling its movement and for selecting appropriate sensors.

Relevant characteristics may be narrowed if the overall strategy focuses on specific types of DFG targeted for removal. As the properties (size, color, spectral characteristics, etc.) are defined for the desired type of DFG, this information must be relayed to remote sensing developers and modelers for their efforts.

Empirically testing the behavior of nets in the ocean was identified as another important step. Some poorly understood processes include the rate at which nets are separated from attached floats and buoys, the rate at which nets become fouled and sink, how quickly and at what depth the fouling organisms die and are eaten or decay, and how quickly or indeed whether these "cleaned" nets then resurface or whether they continue to sink below some depth.

Conducting field experiments by attaching satellite tags to DFG can provide empirical data on the relationship between DFG movement and oceanographic conditions (wind speed, water currents, weather, swells, etc). Also poorly understood is how and where nets and lines create the tangled piles that are removed from the reefs and shorelines of the NWHI.

Characteristics of Operational Environment

The goal of this sub-strategy is to provide information needed to select the appropriate sensors and sensor platforms for direct detection. Sensors must be able to distinguish between floating or subsurface DFG and the surrounding water, sun glints, and white caps at appropriate spatial scales across the spectrum of environmental conditions. Therefore, the choice of sensor will take into account not only the characteristics of the target but also the environmental factors that might confound measurements, such as the presence of whitecaps or marine mammals that might be difficult to distinguish from manmade materials. Such factors as wind, sun position, cloud cover, wave height, and sea surface characteristics will determine the suitability of various aerial platforms in terms of power needed to fly in certain wind conditions and constraints on launching and recovering aircraft safely during various times of the year.

The main step within this sub-strategy is determining the location and time of year for detection and then developing an operational requirements document. This can be used by the sensor and sensor platform group to assist in selection of the appropriate system.

Modeling of Derelict Fishing Gear Location

The goal of this sub-strategy is to develop models to forecast location and movement of DFG. There are two reasons to model DFG locations. One is to narrow the search area for direct detection and eventual at-sea removal. The other is to develop a stratified sampling scheme for quantifying the amount of DFG in the oceans. While many oceanographic data sets and circulation models exist, the relationship between circulation, wind, and debris movement is not well understood.

Using both satellite data and profiling drifters, ocean circulation models are available that provide realistic ocean current fields at high resolution. These models are the basis for determining the movement and concentration of DFG. While a general knowledge of DFG concentration is available (e.g., convergent zones), finer resolution on location and movement requires incorporation of processes that drive eddy formation, wind fields, and known characteristics of DFG transport as a response to oceanographic conditions (weather, wind and water currents). This is critical to improve the utility of these predictive models. Accuracy of model predictions could be tested by attaching satellite tags to DFG found at sea and comparing their actual movement to the model's predictions, as well as confirming through direct detection the presence or absence of DFG at predicted locations.

Direct Detection of Derelict Fishing Gear

The goal of this sub-strategy is to develop sensor-platform systems for short- and long-range detection. The design and choice of a system will depend upon the mission goals (e.g., targeting for removal vs. estimating amount), but the steps are common to either goal.

As the characteristics and behavior of DFG under various conditions are determined, the sensor community can provide a list of sensors that can collect data with the appropriate resolution for field testing. A critical aspect of this is to continue to refine the anomaly-detection algorithms used to distinguish DFG at-sea based on data from the sensor array. While data sets for a number of sensor technologies exist to develop and test the detection capabilities of these algorithms, including video, high resolution photographs, LIDAR and thermal imagery, other potentially useful sensors, including hyperspectral imagery and synthetic-aperture radar (SAR), have not been tested with DFG targets.

Ideally, field tests would occur at a permanent testing site equipped with anchored DFG at known locations. Fields tests may indicate which of the selected sensors perform best at detecting targeted DFG. Once the best-performing sensors have been identified, their specifications (size, weight, electrical needs, etc.) and characteristics of the operational environment can be used to select or design the sensor platform. Proposed short- and long-range platforms could be tested at the permanent testing site to select the most effective. Comprehensive in-field testing of short- and long-range platforms will be required to make adjustments before final implementation.

Specific steps needed to achieve direct detection of DFG include the following:

1. Identify candidate sensor suite based on characteristics of DFG.
2. Develop permanent testing site.
3. Develop partnerships for preliminary testing.
4. Run preliminary sensor tests.
5. Determine potential platforms based on defined environmental conditions and sensor requirements.
6. Conduct systems analysis of down-selected options: sensor + platform + bounded environment.
7. Build prototype of selected sensor-platform combo.
8. Test selected sensor-platform combo in the field.

Next Steps

Two themes came through in the closing discussion: a desire to expand, refine, and distribute the background papers, and the need to attract partners and funding to implement the detection strategy. To address the first item, two potential methods were discussed: publication and broader-than-usual distribution of a NOAA Technical Memorandum and publication of a special issue of a scientific journal. To address ways to attract partners and funding for implementing the strategy, suggestions were made to better quantify the impacts of *not* detecting and removing derelict fishing gear so that a compelling cost-benefit argument could be made.

Additionally, it was felt that a compelling, carefully crafted, and easily understood summary of the project and needs should be developed and shared among workshop participants. This “elevator pitch” as well as more detailed information could be made available to participants so they would be poised to intrigue and attract emerging partnership and funding possibilities from outside the world of marine debris.

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APPENDIX I. Table of Contents from Collection of Background Papers

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APPENDIX II. Agenda

Tuesday, December 9, 2008		
Introduction	8:00 – 8:30	Registration/check-in
	8:30 – 8:45	Opening remarks – Mike Seki
	8:45 – 9:30	Introduction of Participants
	9:30 – 9:45	Workshop Introduction
	9:45 – 10:00	Workshop Overview
	10:00 – 10:15	BREAK
Session 1: State of Knowledge	**Panel I**	**Marine debris - Presentations**
	10:15 – 10:30	Charles Moore, AMRF
	10:30 – 10:45	Russell Reardon, CRED
	10:45 – 11:15	Panel Discussion
	Panel II	**Oceanography – Presentations**
	11:15 – 11:30	Evan Howell, PIFSC
	11:30 – 11:45	Nikolai Maximenko, UH
	11:45 – 12:00	Paulo Calil, UH
	12:00 – 12:30	Panel Discussion
	12:30-1:30	LUNCH
Session 1: State of Knowledge (Cont'd)	**Panel III**	**Technology – Presentations**
	1:30-1:45	Tim Veenstra, ATI
	1:45-2:00	Dave Foley, NOAA
	2:00-2:15	Bill Pichel, NOAA
	2:15-2:45	Panel Discussion
	2:45-3:00	BREAK
Session 2: Gaps	3:00-5:00	Break-out groups to identify and group knowledge gaps

Wednesday, December 10, 2008		
	8:00-8:30	Recap Day 1
Session 2: Gaps (Cont'd)	8:30-10:00	Break-out groups to link gaps and identify strategic actions
	10:00-10:30	Break + Gallery Walk
Session 3: Strategic Planning	10:30-12:00	Break-out groups by discipline to develop strategic actions
	12:00-1:30	Lunch
Session 3: Strategic Planning (Cont'd)	1:30-2:00	Work on group presentations
	2:00-2:30	Group presentation and Q&A for Marine Debris
	2:30-2:45	Break
Session 4: Next steps	2:45-3:15	Group presentation and Q&A for Oceanography
	3:15-3:45	Group presentation and Q&A for Technology
	3:45-4:45	Priorities and next steps
	4:45-5:00	Closing remarks – Robbie Hood

APPENDIX III. Participants

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APPENDIX IV. Presentations

Marine Debris At-Sea Detection and Removal Workshop:

Opening Remarks

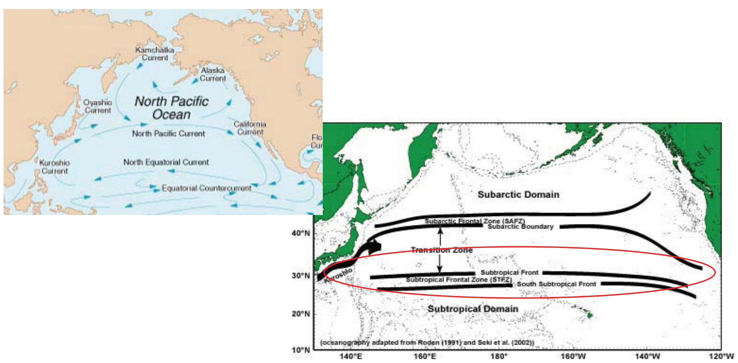
December 9-10, 2008
Honolulu, Hawaii

Workshop Goals:

- Solutions to locating pelagic debris
- Census of marine debris

Pacific Islands Fisheries Science Center

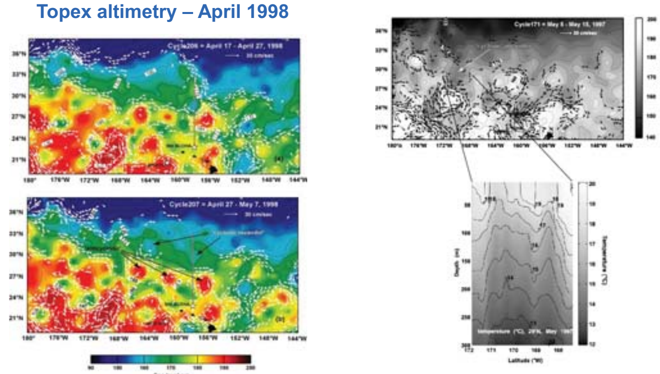
Large scale oceanography – driver for long term distribution



Pacific Islands Fisheries Science Center

Mesoscale eddies, meanders, & jets characterizes the region's complex flow field and "local-scale" operations

Topex altimetry – April 1998



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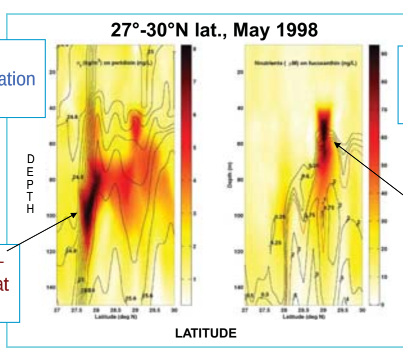
Enhanced chloropigment responses to physical environment also reflect substantial increases in large eukaryotic phytoplankton; namely diatoms & dinoflagellates, suggesting enhanced transfer efficiency to higher trophic levels at these dynamic areas.

Isopycnals (σ_t) on peridinin concentration (mg/m^3)



N+N isopleths on fucoxanthin concentration (mg/m^3)

SSTF interface – note increases at depth!

Embedded cyclonic meander … red contour is nutricline defined as 1M N+N isopleth

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- A question of scale?
  - Gyre circulation
  - Basin- scale fronts
  - Mesoscale meanders & eddies
- … and why do we care?
  - Regions of Convergence & Divergence (re: accumulation, census influence)
  - Energy (trophic) transfer dynamics
  - Natural hotbeds for fisheries, marine mammals, sea turtles, & seabird interactions

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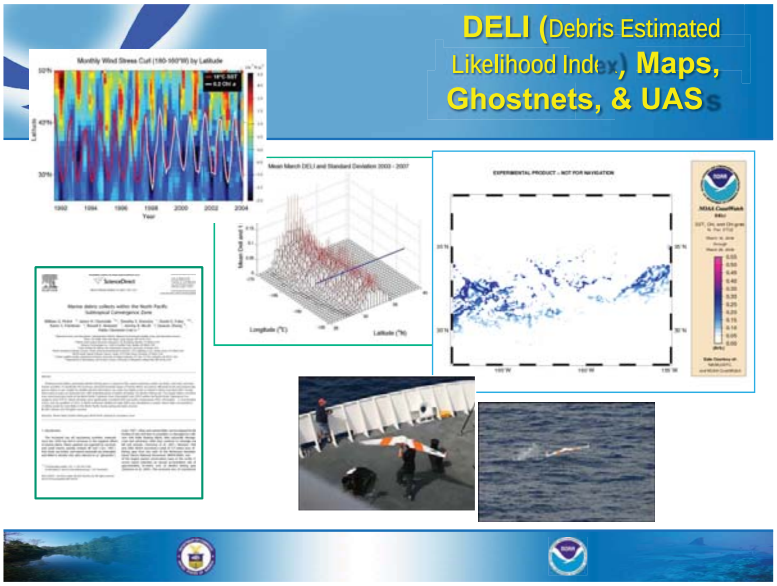
DELI (Debris Estimated Likelihood Index), Maps, Ghostnets, & UASs
Monthly Wind Stress Curl (180-160°W) by Latitude
Mean March DELI and Standard Deviation 2003 - 2007
EXPERIMENTAL PRODUCT – NOT FOR NAVIGATION

Introduction

Kris McElwee
NOAA Marine Debris Program

At-Sea Detection and Removal Workshop
Marine Debris
December 9-10, 2008
Honolulu, Hawai'i

Background

- Loss of fishing gear – large nets, persistent
- Impacts entanglement, coral damage, ghost fishing



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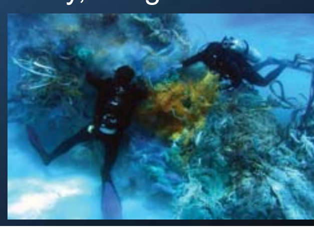
Background

- Loss of fishing gear – large nets, persistent
- Impacts entanglement, coral damage, ghost fishing
- Cleanup efforts in NWHI costly, dangerous

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Background

- Loss of fishing gear – large nets, persistent
- Impacts entanglement, coral damage, ghost fishing
- Cleanup efforts in NWHI costly, dangerous
- Amount and distribution of derelict fishing gear in near-surface waters unknown

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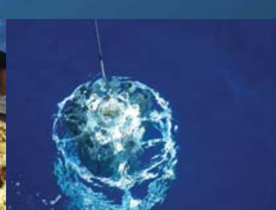
Workshop Genesis


- NOAA at-sea cruise with ATI in 2008 – involved marine debris, oceanography, and technology experts

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Opportunities

- GhostNet Project – 2001 to present
- Papahānaumokuākea Marine National Monument declaration – 2006
- Marine Debris Research, Prevention, and Reduction Act – 2006

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Marine Debris Ac

- Establishes NOAA Marine Debris Program – components, grants, clearinghouse
- U.S. Coast Guard – improve Annex V implementation, NRC study
- Re-establishes Interagency Marine Debris Coordinating Committee

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NOAA Program Com

- Mapping, identification, impact assessment, prevention, and removal efforts
- Reduce adverse impacts of lost and discarded fishing gear
- Outreach and education

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Hard Questions

- What is the mass balance of DFG?
- How well do we understand the impacts of DFG on natural resources of interest?
- What is the cost (both economic and ecological) of removing DFG at sea compared to the cost of removing it from reefs and other habitats?

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Why We're Here

- Take stock of marine debris, oceanography, and technology knowledge and gaps around these objectives
  - Locate derelict fishing gear for removal
  - Discuss a census of marine debris
- Develop strategic action plan to fill gaps
- Build interdisciplinary collaboration and partnerships

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Focus of W

- Solutions that draw on more than one discipline
- *Detecting* derelict fishing gear <u>at sea</u>

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ill Follow

- Revised draft background paper
- Policy changes and funding are not guaranteed
- A plan that allows us to move quickly to capture opportunities

Workshop Mechanics

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Workshop Objectives

- Take stock of marine debris, oceanography, and technology knowledge and gaps around these objectives
  - Locate derelict fishing gear for removal
  - Discuss a census of marine debris
- Develop strategic actions to fill gaps
- Build interdisciplinary collaboration and partnerships

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Workshop Overview

Session 1: State of Knowledge

Session 2: Gap Mapping

Session 3: Strategic Planning

Session 4: Next Steps

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Session 1: State of Knowledge

- Describe our state of knowledge in three key topic areas:
  - **Marine debris:** What are the sources, characteristics, and behavior of marine debris at sea?
  - **Oceanography:** What are the oceanographic processes that transport or move marine debris at sea?
  - **Technology:** What technology is available or needed to help detect and track marine debris for removal at sea?

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Session 1 – cont'd

- For each topic area
  - 10 minute presentations based on the background paper
  - 5 minutes clarifying questions
  - Panel discussion to:
    - Add to the list of knowns
    - Identify other information and data sources including past and ongoing studies and literature

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Session 2: Gaps – Commonalities

- What do we need to know to improve our capability to <u>detect</u> marine debris at sea?
  - Review knowledge gaps identified from background papers
  - Identify commonalities
  - Add or delete gaps
  - Set the stage for action planning

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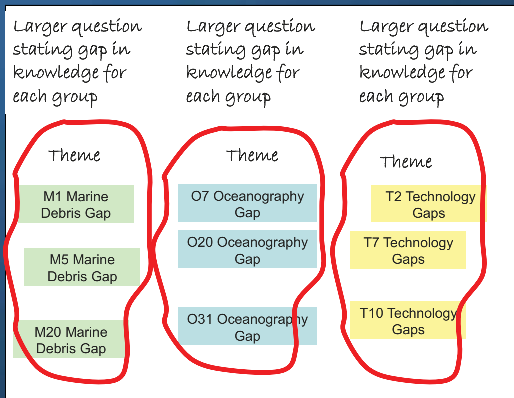
Mapping Gaps – Day 1



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Session 2: Gaps – Linkages

Define linkages between gaps in knowledge

- Develop a logical sequence of questions
- Identify strategic actions drawing on one or more disciplines to address gaps

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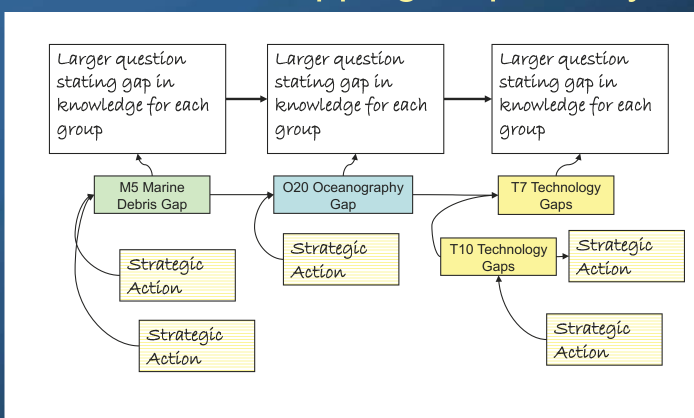
Session 2 : Mapping Gaps - Day 2



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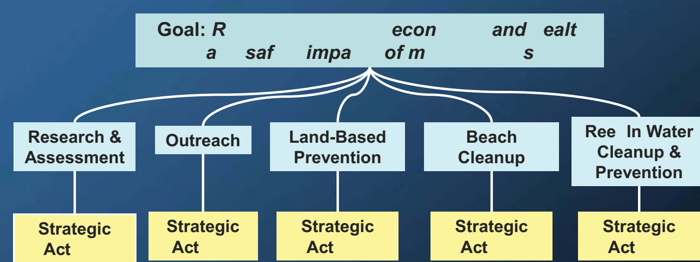
Hawaii Marine Debris Action Plan



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Session 3: Action Planning

Goal: *Reduce ecological, economic, and health and safety impacts of marine debris*

Objective: To increase our capability to detect marine debris at sea

Strategic Actions

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Strategic Action Template

- Action needed (short title):
- What gap does this action address and how?
- What are steps to carrying out this action?
- What organizations and individuals need to be involved, and how?
- Who has the technology, expertise, resources, materials to carry this out?
- What are impediments to carry out this action?
- Are there other (non-marine debris) benefits to this action?

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Session 4: Next Steps

- Identify opportunities to partner and leverage
- Identify key priorities
- Next steps for the plan and background paper

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O
D S

CAPTAIN CHARLES MOORE
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North Pacific Subtropical Gyre
Voyages Looking for
Ghost Nets
1999, 2000, 2002 (2), 2005, 2007, 2008

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ORV ALGUITA

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ORV Alguita: Manta Trawl

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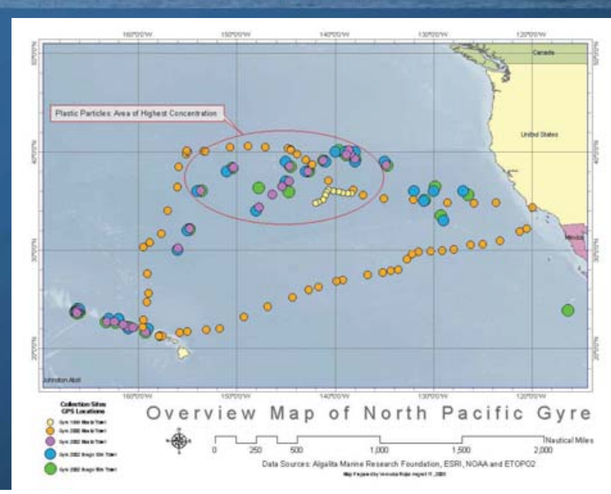

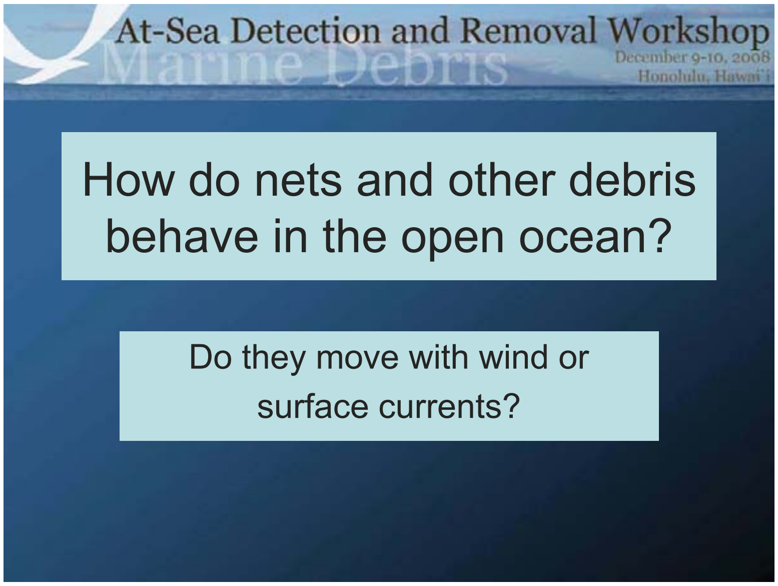
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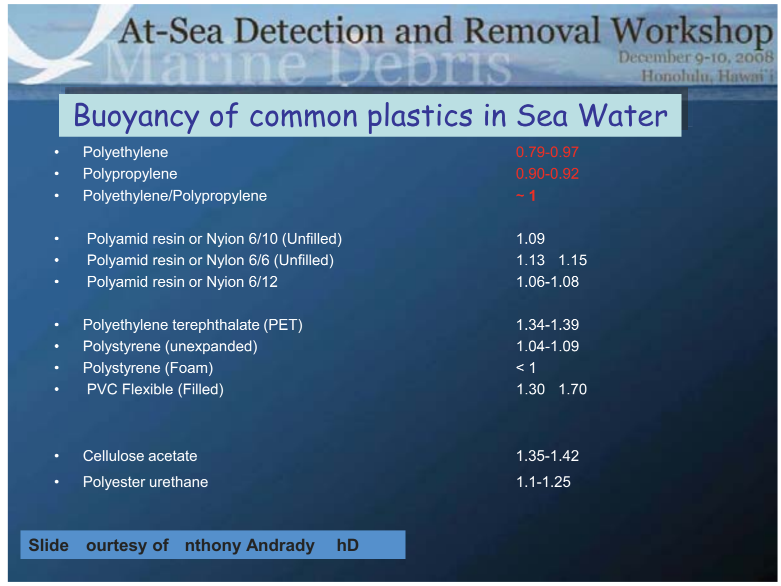
How do nets and other debris behave in the open ocean?
Do they move with wind or surface currents?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Buoyancy of common plastics in Sea Water
Polyethylene 0.79-0.97
Polypropylene 0.90-0.92
Polyethylene/Polypropylene ~ 1
Polyamid resin or Nylon 6/10 (Unfilled) 1.09
Polyamid resin or Nylon 6/6 (Unfilled) 1.13 1.15
Polyamid resin or Nylon 6/12 1.06-1.08
Polyethylene terephthalate (PET) 1.34-1.39
Polystyrene (unexpanded) 1.04-1.09
Polystyrene (Foam) < 1
PVC Flexible (Filled) 1.30 1.70
Cellulose acetate 1.35-1.42
Polyester urethane 1.1-1.25
Slide ourtesy of nthony Andrady hD


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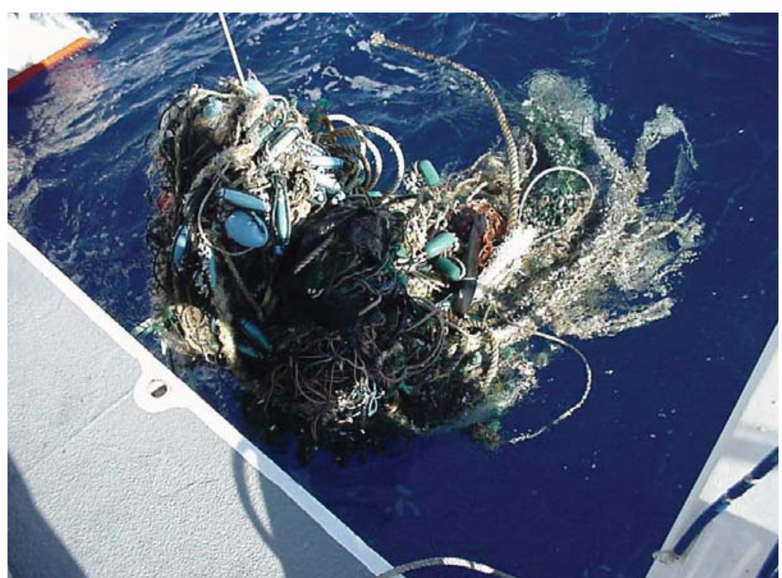
Buoy on Drogue Marking Net

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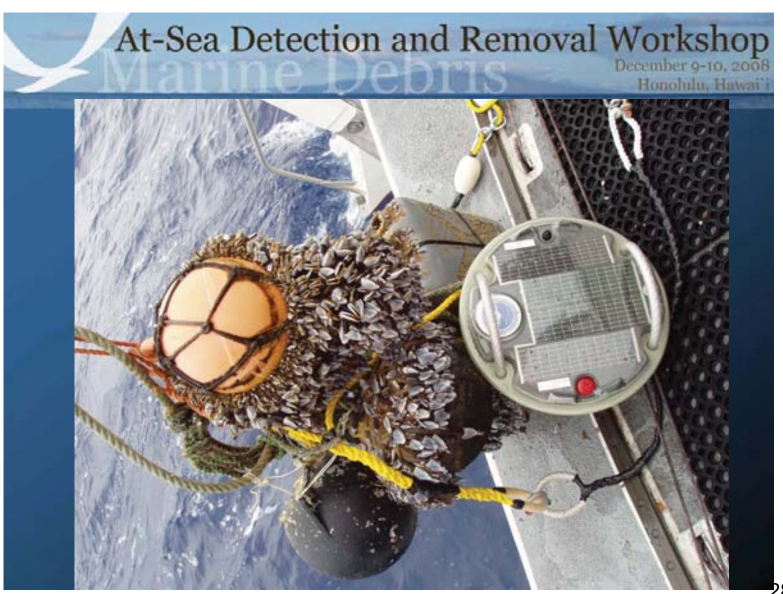
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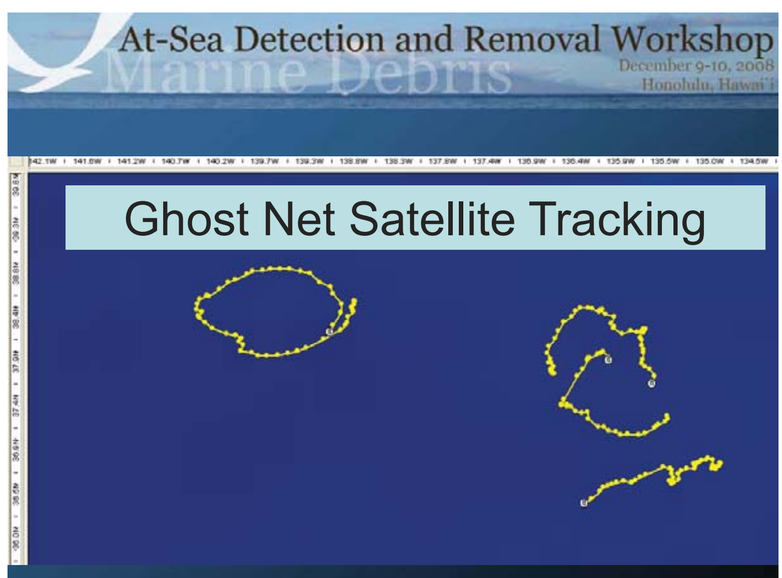
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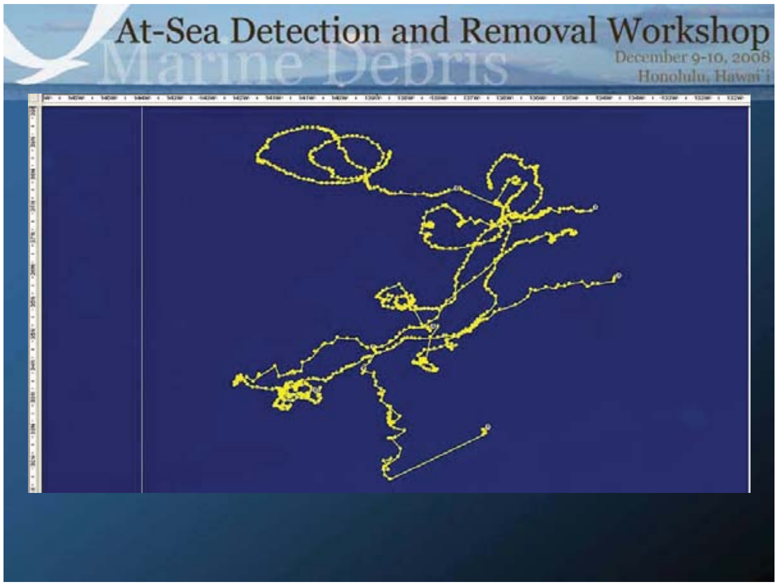
Ghost Net Satellite Tracking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ESPERANZA
AMSTERDAM


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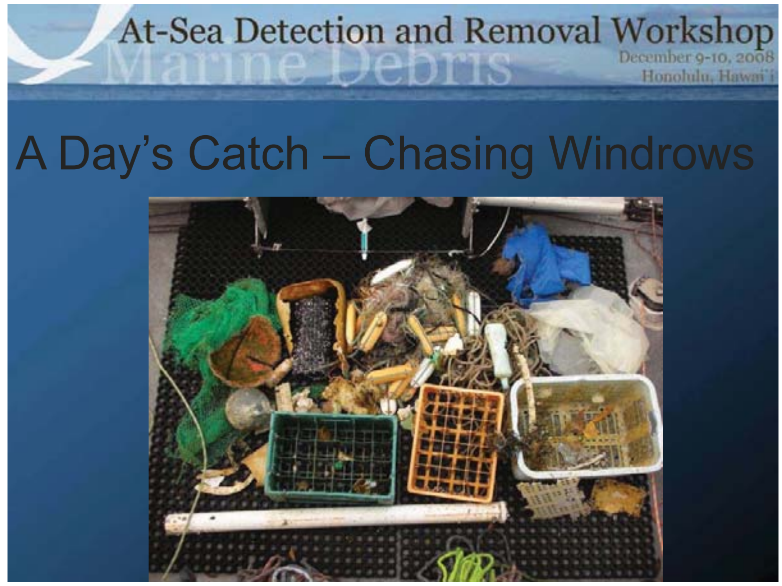
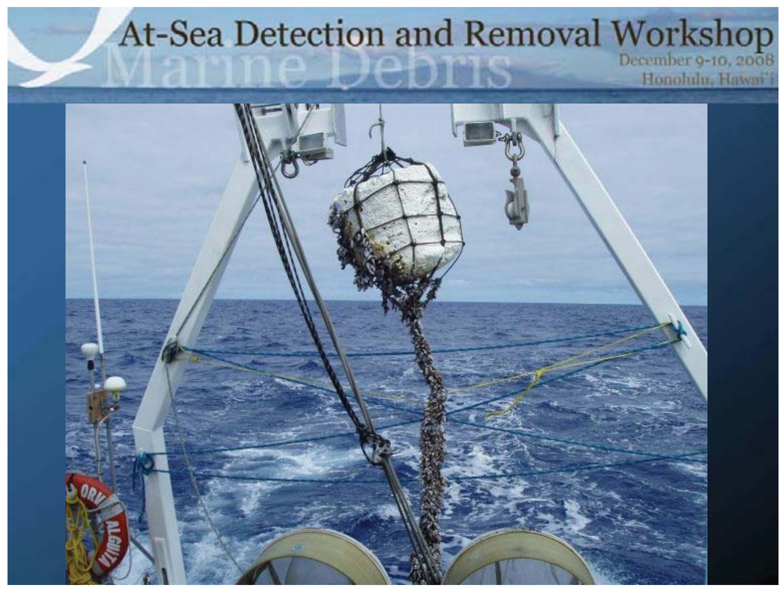
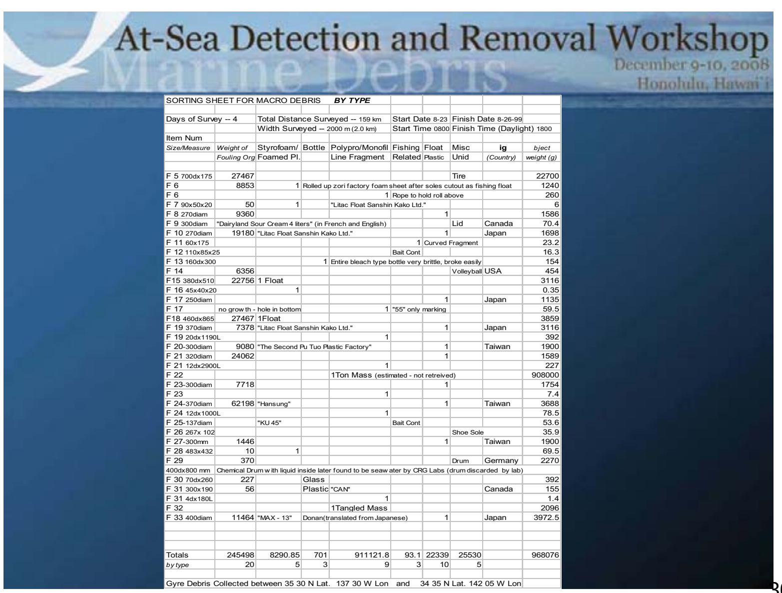
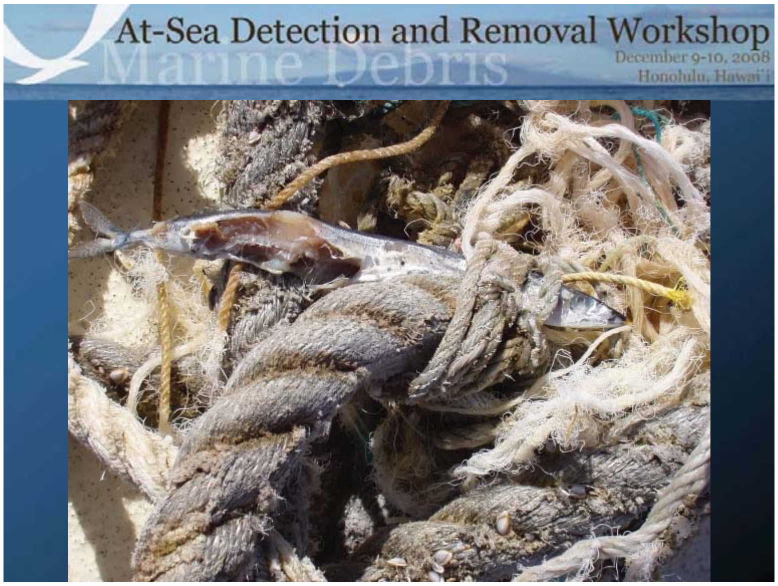






SORTING SHEET FOR MACRO DEBRIS ***BY TYPE***									
Days of Survey -- 4		Total Distance Surveyed -- 159 km			Start Date 8-23		Finish Date 8-26-99		
		Width Surveyed -- 2000 m (2.0 km)			Start Time 0800		Finish Time (Daylight) 1800		
Item Num									
Size/Measure	*Weight of Fouling Org*	Styrofoam/ Foamed Pl.	Bottle	Polypro/Monofil Line Fragment	Fishing Related	Float Plastic	Misc Unid	**ig** *(Country)*	*bject weight (g)*
F 5 700dx175	27467						Tire		22700
F 6	8853	1	Rolled up zori factory foam sheet after soles cutout as fishing float						1240
F 6				1	Rope to hold roll above				260
F 7 90x50x20	50	1		"Litac Float Sanshin Kako Ltd."					6
F 8 270diam	9360					1			1586
F 9 300diam	"Dairyland Sour Cream 4 liters" (in French and English)						Lid	Canada	70.4
F 10 270diam	19180	"Litac Float Sanshin Kako Ltd."				1		Japan	1698
F 11 60x175					1	Curved Fragment			23.2
F 12 110x85x25					Bait Cont				16.3
F 13 160dx300			1	Entire bleach type bottle very brittle, broke easily					154
F 14	6356						Volleyball	USA	454
F15 380dx510	22756	1 Float							3116
F 16 45x40x20		1							0.35
F 17 250diam						1		Japan	1135
F 17	no grow th - hole in bottom			1	"55" only marking				59.5
F18 460dx865	27467	1Float							3859
F 19 370diam	7378	"Litac Float Sanshin Kako Ltd."				1		Japan	3116
F 19 20dx1190L				1					392
F 20-300diam	9080	"The Second Pu Tuo Plastic Factory"				1		Taiwan	1900
F 21 320diam	24062					1			1589
F 21 12dx2900L				1					227
F 22				1Ton Mass (estimated - not retreived)					908000
F 23-300diam	7718					1			1754
F 23				1					7.4
F 24-370diam	62198	"Hansung"				1		Taiwan	3688
F 24 12dx1000L				1					78.5
F 25-137diam		"KU 45"			Bait Cont				53.6
F 26 267x 102							Shoe Sole		35.9
F 27-300mm	1446					1		Taiwan	1900
F 28 483x432	10	1							69.5
F 29	370						Drum	Germany	2270
400dx800 mm	Chemical Drum w ith liquid inside later found to be seaw ater by CRG Labs (drum discarded by lab)								
F 30 70dx260	227		Glass						392
F 31 300x190	56		Plastic	"CAN"				Canada	155
F 31 4dx180L				1					1.4
F 32				1Tangled Mass					2096
F 33 400diam	11464	"MAX - 13"	Donan(translated from Japanese)			1		Japan	3972.5
Totals	245498	8290.85	701	911121.8	93.1	22339	25530		968076
by type	20	5	3	9	3	10	5		
Gyre Debris Collected between 35 30 N Lat. 137 30 W Lon and 34 35 N Lat. 142 05 W Lon									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JELLYFISH ENTANGLED IN NET FISHING LINE


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Valella Vallela captured in Manta Trawl Sample/333micron mesh


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Valella Valella with Plastic Particle embedded / Angel White of C-MORE/OSU


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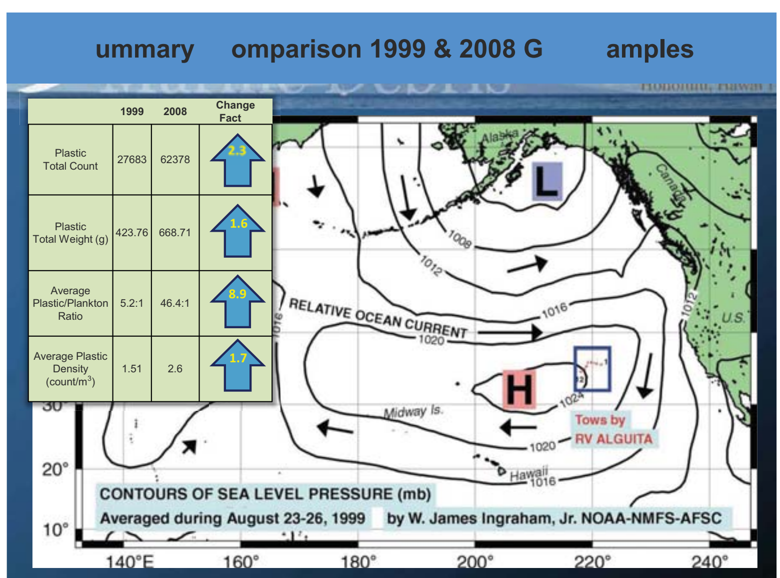
Valella Valella with several plastic particles / Angel White of C-MORE/OSU


ummary omparison 1999 & 2008 G amples
1999
2008
Change Fact
Plastic Total Count
27683
62378
2.3
Plastic Total Weight (g)
423.76
668.71
1.6
Average Plastic/Plankton Ratio
5.2:1
46.4:1
8.9
Average Plastic Density (count/m3)
1.51
2.6
1.7
Alaska
Canada
L
H
U.S.
RELATIVE OCEAN CURRENT
Midway Is.
Hawaii
Tows by RV ALGUITA
CONTOURS OF SEA LEVEL PRESSURE (mb)
Averaged during August 23-26, 1999
by W. James Ingraham, Jr. NOAA-NMFS-AFSC
140°E
160°
180°
200°
220°
240°
20°
10°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Myctophid, Sp.
90% Mesopelagic Biomass


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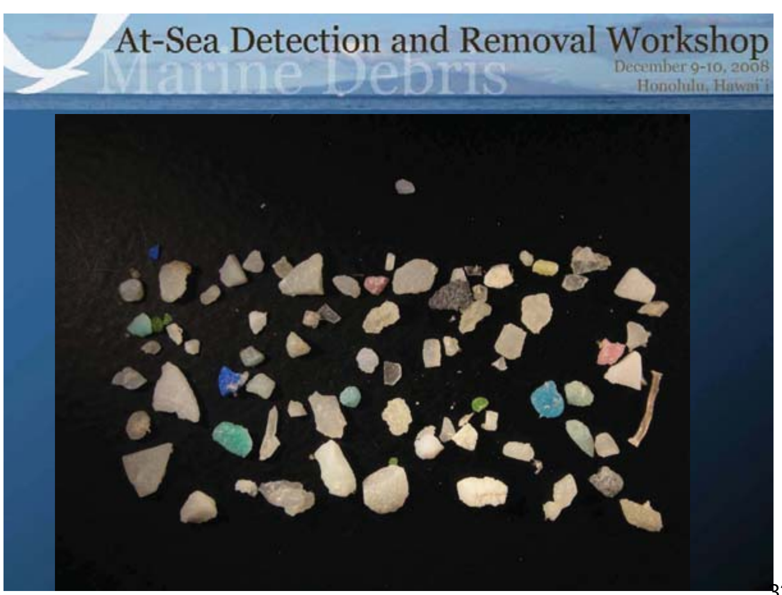
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Plastic fragments found in 5-week old rainbow runner
caught at 23º05.35N, 147º12.86W on August 13, 2008.
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5 cm

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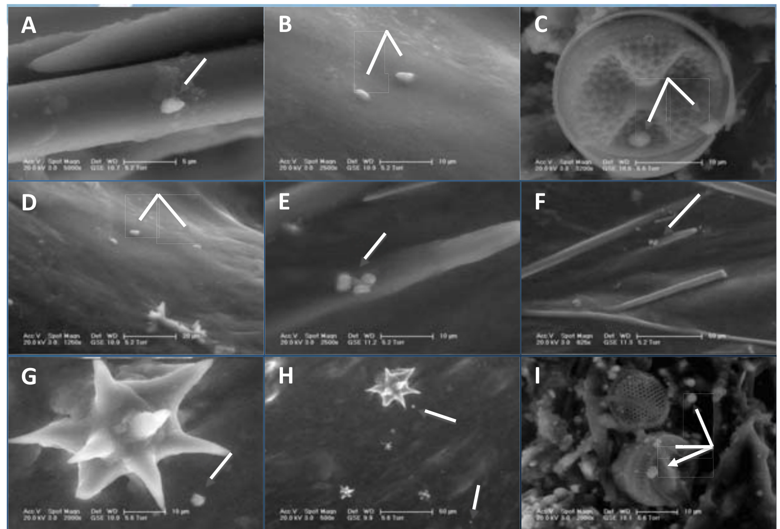
Nanoparticles Affect Reef Sponges, eg. Tethya aurantia

Slide Courtesy Andrea Neal, PhD.

Nanoscale titanium dioxide (TiO_2) is produced commercially for widespread use in pigments, plastics, cosmetics, and sunscreens.

In 2008, Danavaro et al. estimated that at least 25% of applied sunscreen is washed off during swimming and bathing, accounting for a potential release of 4,000–6,000 tons/year of sunscreen in reef areas

Tethya aurantia incubated for four hours in 0.0125 mg/ml of industrial titanium dioxide approximately 40nm ESEM images were acquired with a FEI Co. XL30 FEG ESEM (Philips Electron Optics, Eindoven, The Netherlands). Imaging was in wet mode at 5.2 Torr, 5 C, using an accelerating voltage of 20 kV. Specimens were not conductively coated prior to imaging. Location of titanium dioxide was confirmed utilizing EDS (Elemental detection analysis) A. Outer sponge spicule with titanium dioxide nanoparticle aggregate, B. Inner sponge tissue with titanium dioxide nanoparticle aggregate, C. Diatom in outer sponge tissue with titanium dioxide nanoparticle aggregate.) D.. Inner sponge tissue with titanium dioxide nanoparticle aggregate,) E,F. spicule with titanium dioxide nanoparticle aggregate, G, H. Inner sponge tissue and megasters with titanium dioxide nanoparticle aggregate, I. Diatoms in outer sponge tissue with titanium dioxide nanoparticle aggregates.



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At-Sea Detection and Removal of Derelict Fishing Gear

NOAA Cruise Experience

Kyle Koyanagi, Chief Scientist OES 08 02

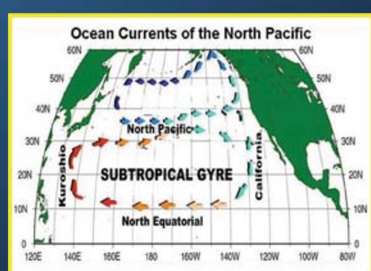
JIMAR Marine Debris Operations Manager
NOAA PIFSC Coral Reef Ecosystem Division

Introduction / Background

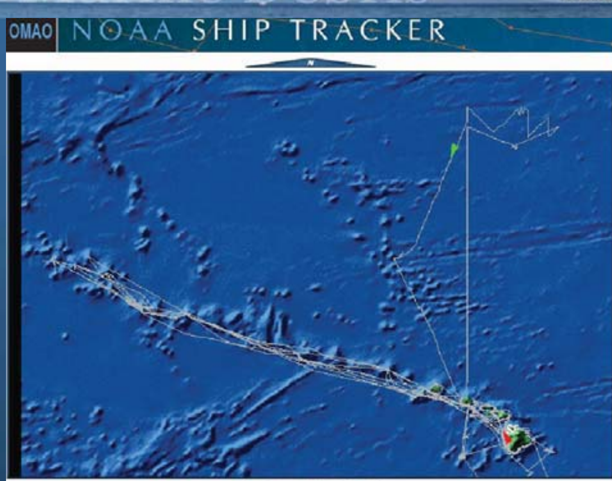
- Programs to identify, locate, track and remove debris while at-sea may become an important and complementary effort to ongoing nearshore, reef, and beach clean up efforts.
- At-sea removals would prevent subsequent environmental impacts to fragile nearshore ecosystems from large conglomerates of marine debris.

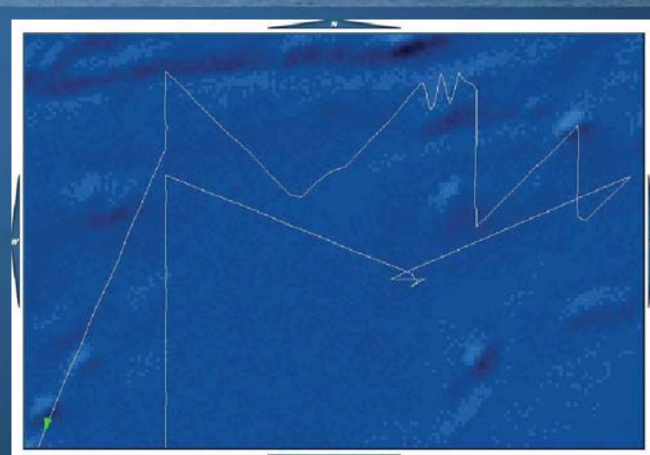
OES 08 02

- A 17-day experimental effort (MAR 24-APR 9, 2008) to detect and remove marine debris in the North Pacific Sub-Tropical Convergence Zone (STCZ), conducted aboard the NOAA Ship *Oscar Elton Sette,* shed light on some of the operational challenges ahead.



Oscar Elton Sette





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Marine Debris Detection Methods Used on OES 08 02

- Debris Estimated Likelihood Index (DELI) maps
- Hydrographic and Biological Sampling
- Ship based observers using "Big Eye" binoculars
- Unmanned Aircraft System (UAS) surveys

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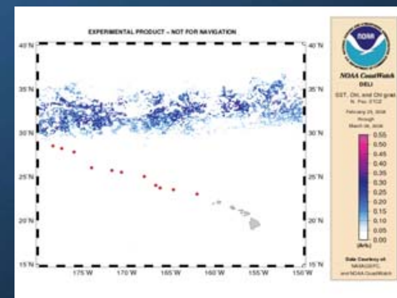
Debris Estimated Likelihood Index (DELI) Maps

Near real-time satellite data (SST, Chl-) was utilized during the cruise to help direct the vessel to the general vicinity of high debris likelihood.



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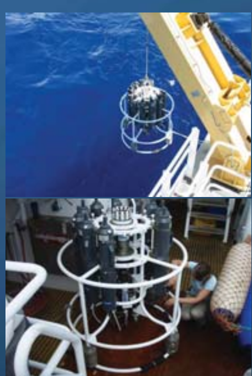
Hydrographic and Biological Water Sampling



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"Big Eye" Binoculars

Visual surveys with 25X150 binoculars from the Flying Bridge (40 ft above the water).

Survey protocols were adapted from ship-based visual cetacean surveys.

3 primary stations: port and starboard Big Eye observers and a data recorder. Types and sizes of marine debris were recorded and specialized software converted distance and bearing into position.

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Unmanned Aircraft System (UAS)

Ship-based UAS test flights were conducted to evaluate UAS technology for marine debris surveys to detect debris targets for removal or attachment of satellite-tracked marker buoys.

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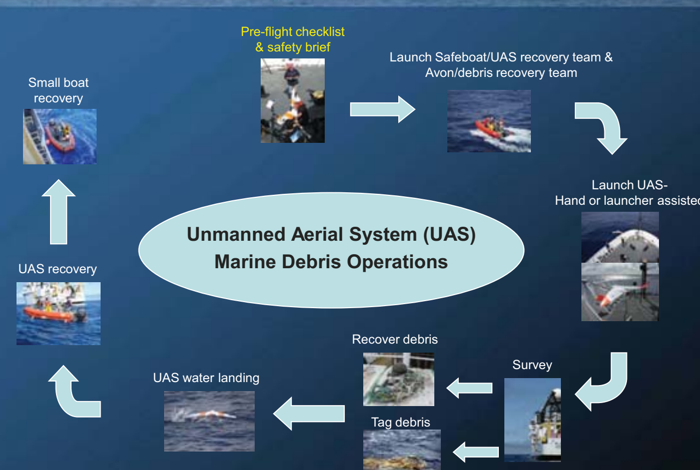

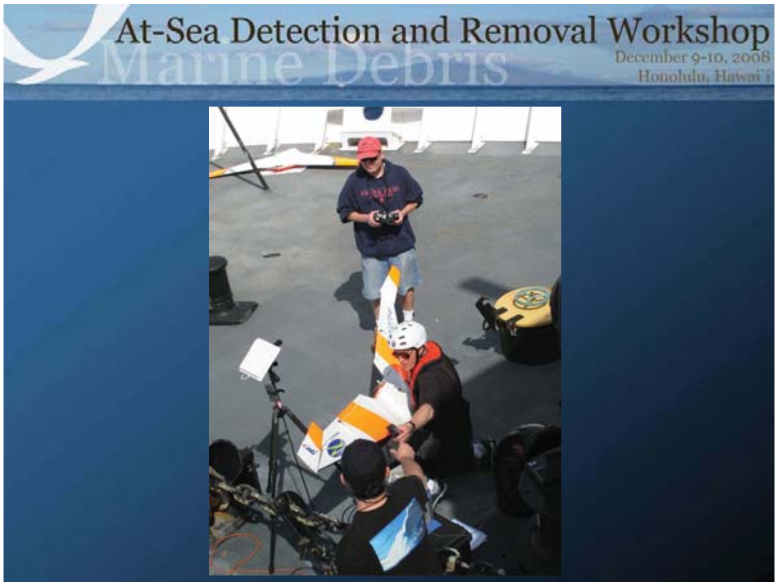
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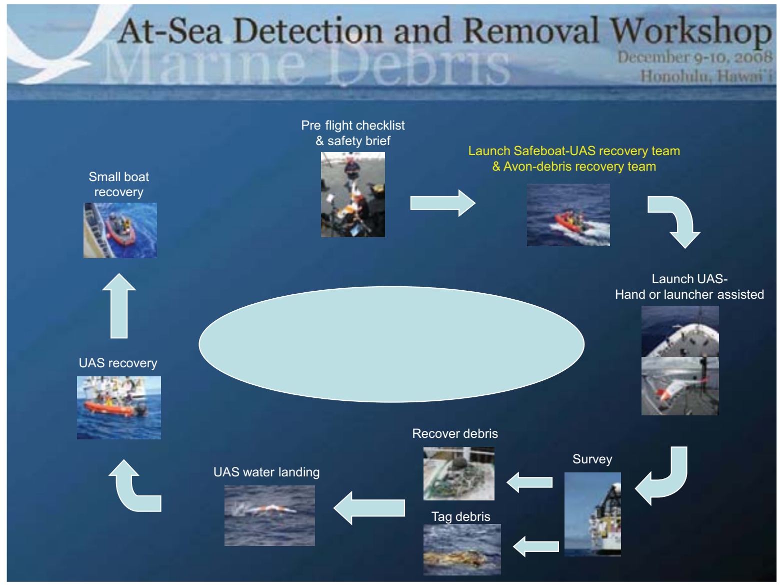
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Pre flight checklist
& safety brief
Launch Safeboat-UAS recovery team
& Avon-debris recovery team
Launch UAS-
Hand or launcher assisted
Survey
Recover debris
Tag debris
UAS water landing
UAS recovery
Small boat
recovery


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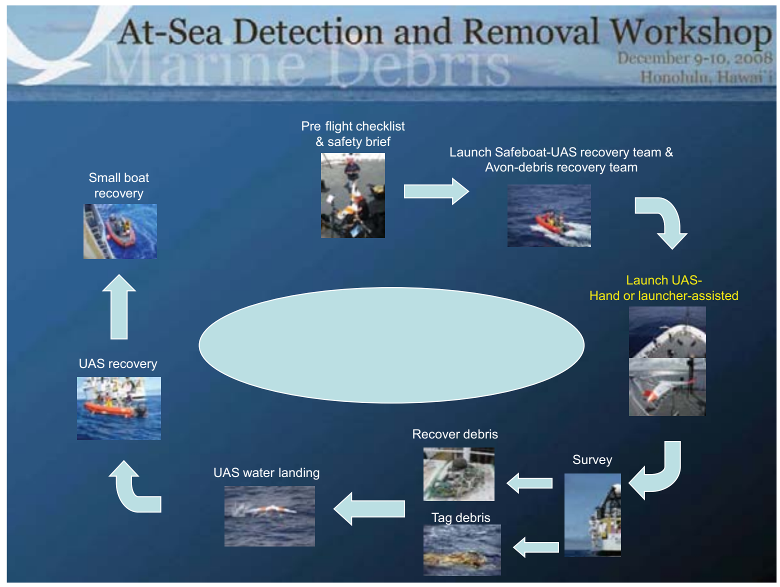
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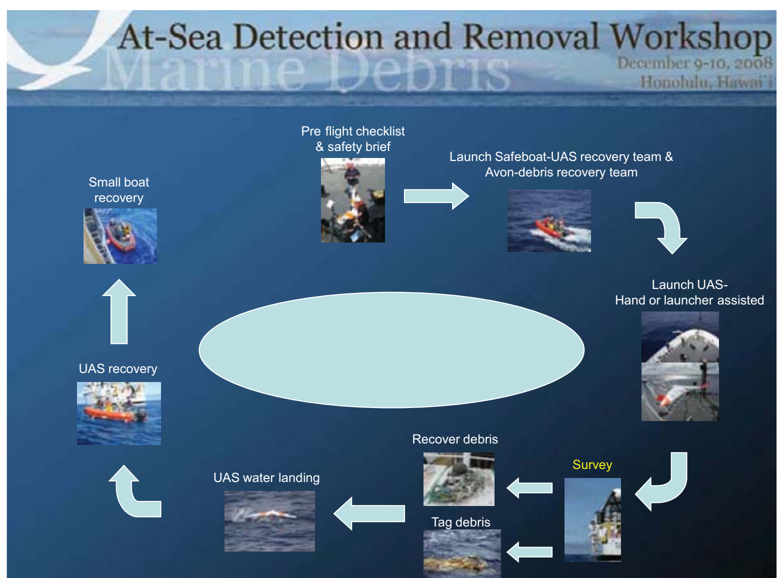
By hand…
Or launcher…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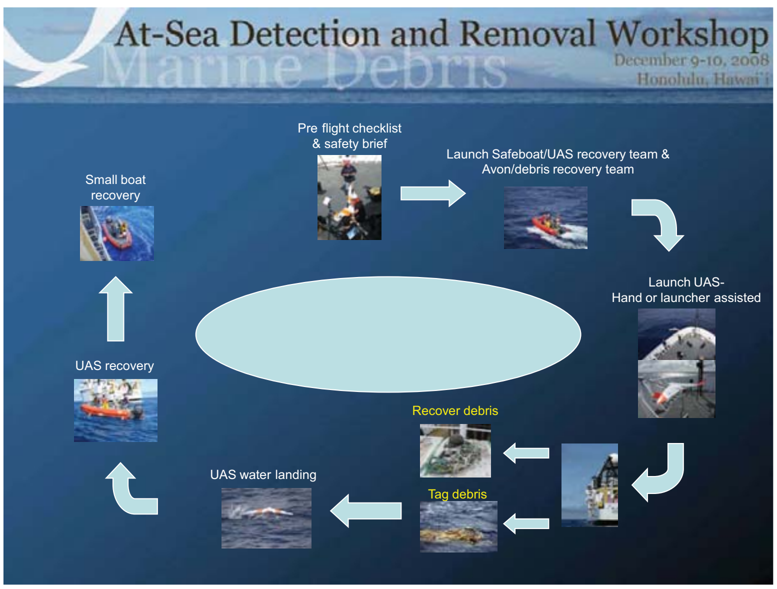
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UAS water landing
UAS recovery
Small boat recovery


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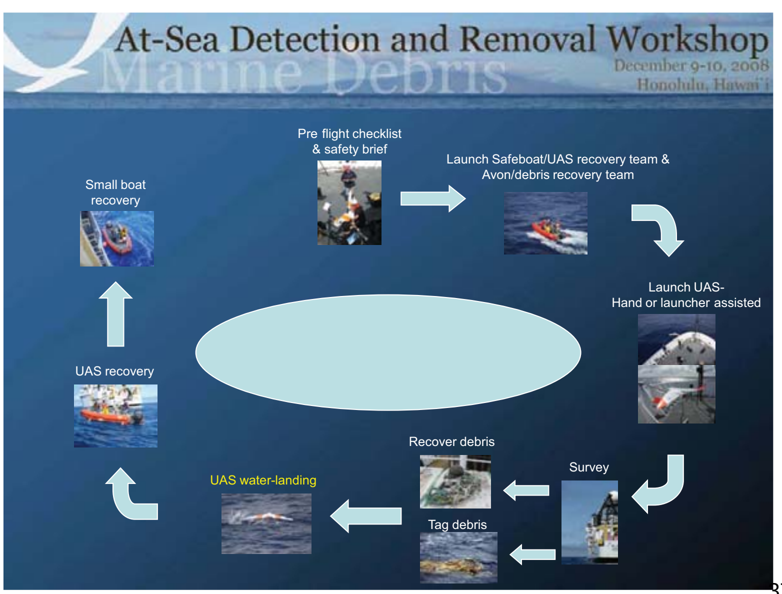
Recovered debris
Tagged debris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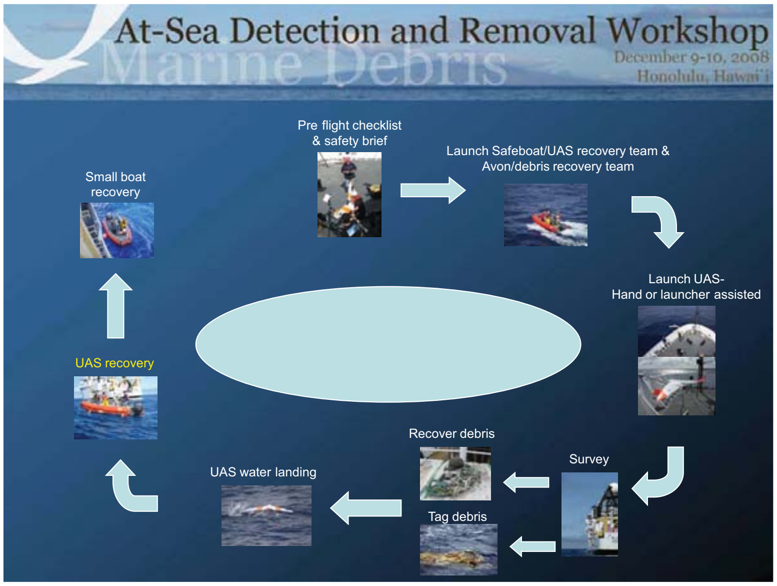
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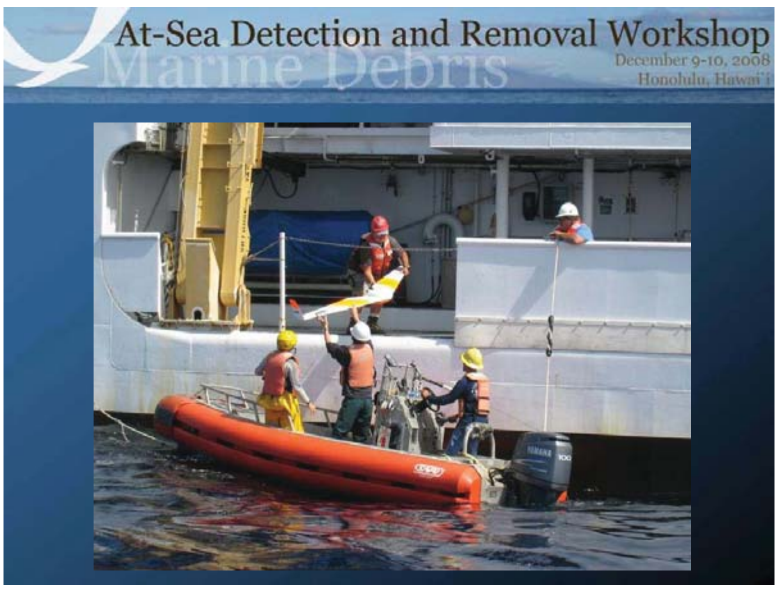
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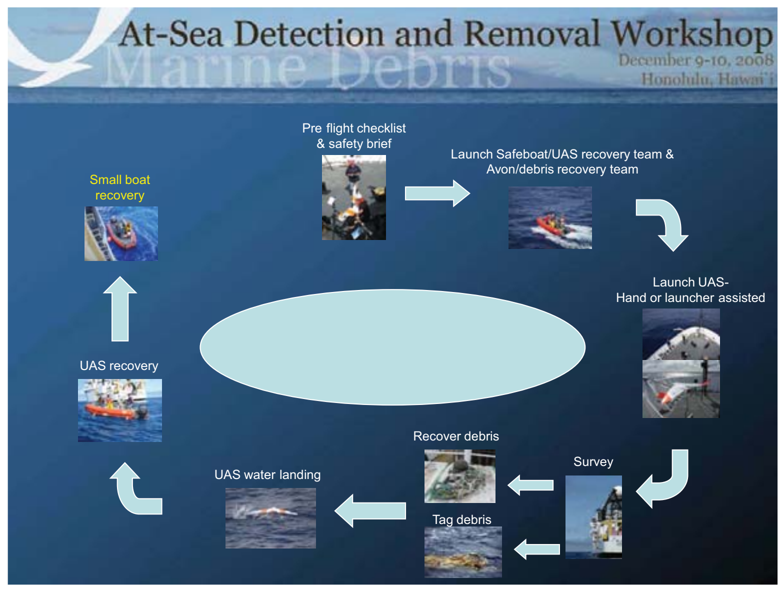
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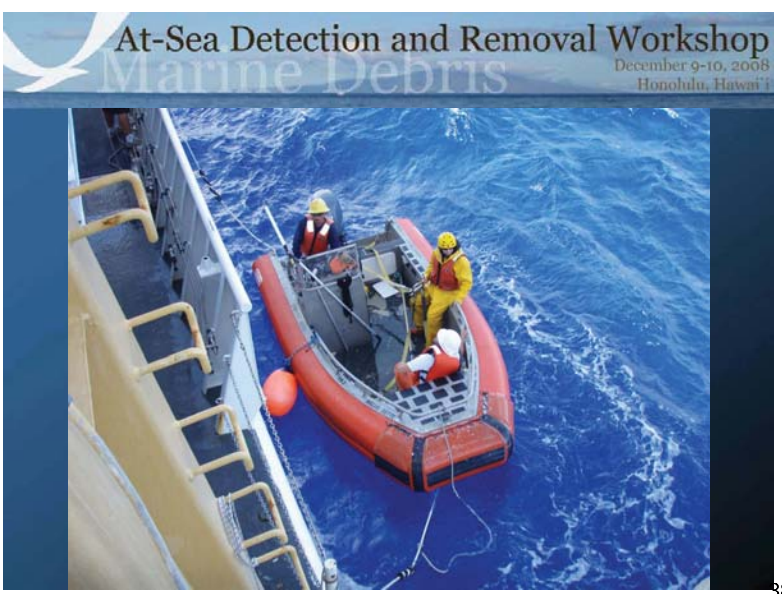
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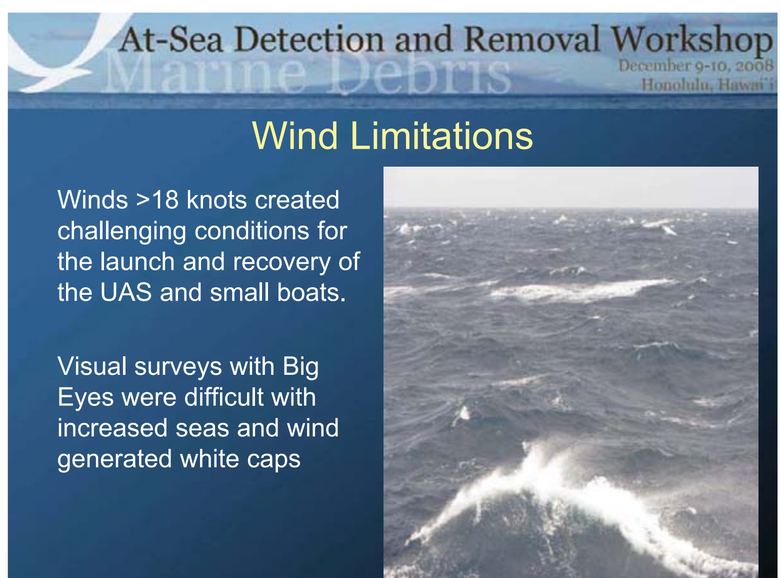
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Wind Limitations
Winds >18 knots created challenging conditions for the launch and recovery of the UAS and small boats.
Visual surveys with Big Eyes were difficult with increased seas and wind generated white caps

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Low Lying Fog and Cloud Limitations

- Satellite data was of limited use (poor coverage).
- UAS was grounded (limited visibility of aircraft or usefulness of video feed).
- Limited range of the “Big Eye” operations.

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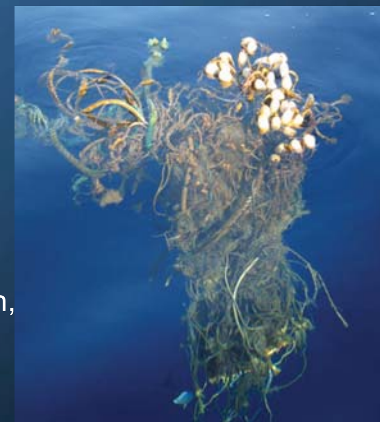
Derelict Fishing Gear Characteristics

DFG tends to float slightly submerged making it challenging to spot unless floats, etc. are attached.

Environmental factors such as rough seas, rain, fog, low light, and glare further increase the spotting difficulty.



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Marine Debris Removal Challenges

Small Boat Operations

- Small boats: maneuverable but limited load capacity
  - Large conglomerates may have to be sectioned
- Dangerous, physical work
- No lee or protected water

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Direct Recovery:

- Ship fouling risk
- Type and condition of debris are factors (poor lift points)
- Overboard risks for crew

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OES 08 02 Cruise Conclusion

Additional ground-truthing and validation of DELI maps would benefit future survey efforts.

A long-endurance (manned or unmanned) aircraft which could fly over the area of interest prior to ship arrival could provide timely observations over a large area and help direct the ship to debris concentrations.

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Cruise Conclusion (Cont.)

Ship-based UAS may be a promising approach to increase the effectiveness of marine debris survey and removal operations…

But, additional work needs to be done to develop and test methodologies, sensors and detection software, particularly for various weather and sea states (e.g. whitecaps) before we attempt a full scale operational effort.

FAA constraints on UAS are a current limiting factor in survey operations.

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Cruise Conclusion (Cont.)

Image stabilization and other technologies would benefit shipboard Big Eye observers. Additional work is needed in estimating debris sizes and densities, including standardizing protocols specific to marine debris and calibration of observers/observing in various weather/sea conditions.

Safe methods with minimal risk to vessel and crew are needed for open ocean removal or tagging of marine debris in challenging weather and sea conditions.

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We know its out there.

Now if we could only find it…

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Debris crew atop 24,000 kg of debris

North Pacific Circulation, Productivity, and Migration

Evan Howell, Carey Morishige, and Michael Seki

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Introduction/Background

- North Pacific Ocean northern part of Earth's largest ocean
- Circulation of upper layers mainly wind-driven
- Characterized by three main "zones" in the north (N of Eq. Zone)
  - Subtropical Gyre –warm, stratified, low chlorophyll waters
  - Subarctic Gyre – cool, vertically mixed, high chlorophyll waters
  - "Transition" zone – Mixture of these two regions
- Transition zone region of high surface convergence (large scale)

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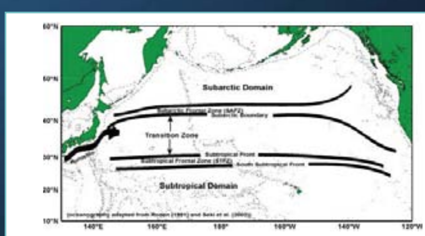
What's Known?

- Surface circulation wind-driven
  - Westerlies north of 30°N
  - Easterly trades to south
- Four main currents: Kuroshio, North Pacific, California and N. Equatorial



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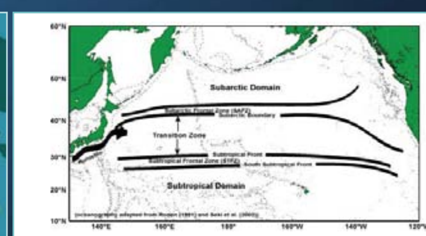
What's Known?

- Two main gyre systems
- South - subtropical gyre (warm, low productivity upper layer)
- Subarctic gyre to the north (cold, more productive upper layer)
- In between is "transition" zone which is mixture of two regions



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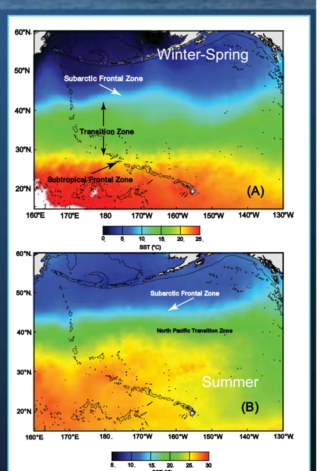
Transition Zone

- Multiple large scale fronts
  - SSTF: 28°- 30°N (~20°C)
  - STF: 32°-34°N (~17°C)
- Distinct seasonal surface signatures ("migrates" north to south)
- Thickness and migration of front also changes to to interannual (ENSO) and decadal events (PDO)
- MD: These events can alter the southern extent of this convergent region (reach NWHI or not)



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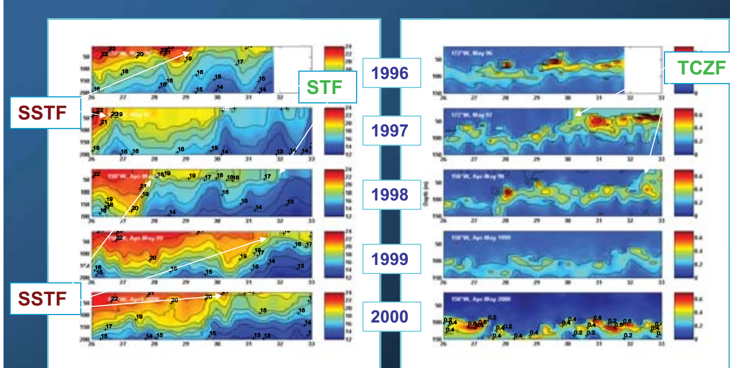
Transition Zone

- Can see extent to depth from subsurface data (17°/20°C)



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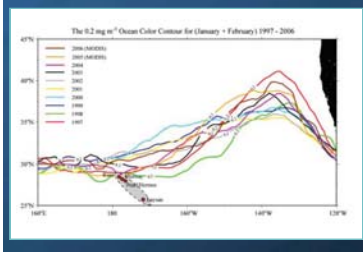
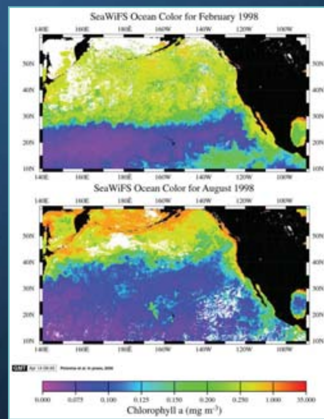
Productivity: TZCF

- Transition zone chlorophyll front
- Proxy for TZ conv/productivity line, roughly STF (~17/18°C)
- Seasonal N-S oscillation min in Jan-Feb, max Jul-Aug
- Depending on year, can reach NWHI
- Also important migration pathway pelagics





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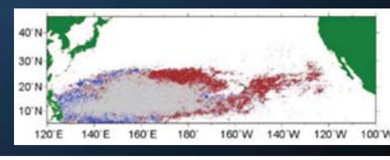
s Very Likely?

- Very likely that we will see effects on system from climate change
- Climate affects transition zone and hence large scale convergence zone in North Pacific
- Also have observed N/NE expansion of oligotrophic NP Subtropical Gyre (warmer, more stratified less productive upper layer)
- Changes in climate may affect ocean in other ways (e.g. ocean acidification)

Change in oligotrophic area in NPSG for December from 1998 2006 (red new area)



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s Not Certain?

- As with everything, additional information is needed on circulation and productivity/biology
- Effects of climate (ENSO, PDO) on variability and structure of transition zone
- More physical and biological subsurface data (e.g. temp, nutrients) is needed (subsurface structure important on certain scales)
- Basic biologic time series (zooplankton, micronekton) are missing for much of the North Pacific

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What is Needed?

1-2 years

- Increased collaboration between climate scientists, oceanographers, and modelers to synthesize results and improve predictive models
- Improved coordination of ocean-monitoring activities among involved entities
- Expansion of spatial and temporal coverage (long term data collection over an increased area)

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What is Needed?

2-5 years

- Synthesize information to quantify relationships among various parts of the ecosystem (~IEA)
- Increase the number of Argo floats with additional instrumentation (e.g., Fluor, O_2, NO_3, PO_4) to measure the subsurface of STCZ

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What is Needed?

>5 years

- Comprehensive ecosystem, ocean-atmosphere, and biophysical models of the North Pacific Ocean are needed, inclusive of the information and data stored and utilized in location-specific models that currently exist
- Additional satellite support for continuation and increase in monitoring efforts is also needed (geostationary with adequate coverage?)

Topic: Modeling Approaches for Locating and Predicting the Movement of Debris

Title: Near-surface currents and debris pathways estimated from drifter trajectories and satellite data

Nikolai Maximenko, University of Hawaii

Collaborators:

Peter Niiler, Scripps Institution of Oceanography

Jan Hafner, University of Hawaii

Cara Wilson, NOAA

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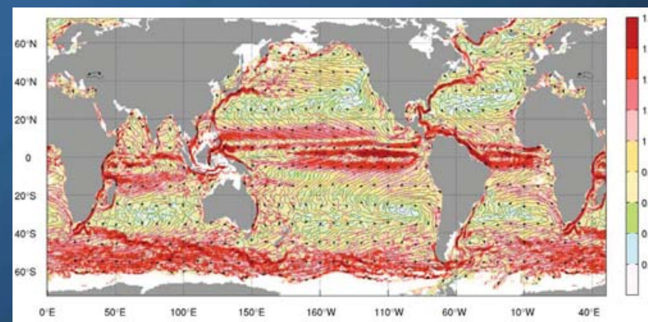
Introduction/Background



Mean near-surface currents as derived from trajectories of >11,000 drifters

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Introduction/Background

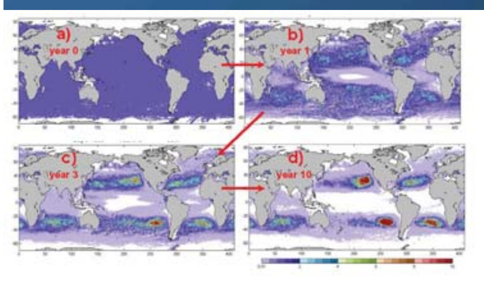
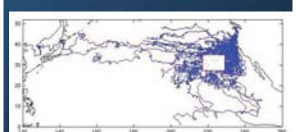
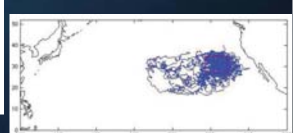


Figure 3. Concentration of density of drifters (or marine debris) from the initially homogeneous state (a) after 1 year (b), 3 years (c) and 10 years of advection by currents, measured by real drifters. Units indicate relative change of the concentration.

Drifter trajectories into the NP convergent zone



Drifter trajectories from the NP convergent zone



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What's Known?

- Most harmful debris is produced by men
- Men-produced debris lives long
- Debris motion is driven by ocean currents and wind
- In mid-latitude subtropical gyres, large amount of debris is collected by converging wind-driven ocean currents

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What's Very Likely?

- Near-surface currents are a combination of geostrophic currents (controled by sea level), Ekman currents (controled by local wind), and high-frequency oscillations (inertial oscillations, tides, surf, etc.)
- Relatively large scale (>100km) geostrophic currents can be derived from satellite altimetry. (1km altimeter is to be launched in 2016).
- Relatively large scale Ekman currents can be derived from satellite winds (QuikSCAT).

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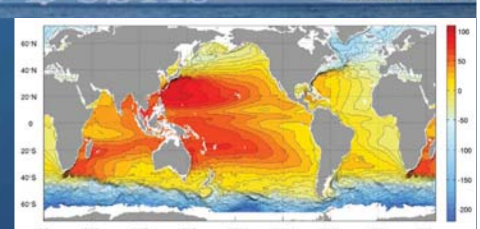
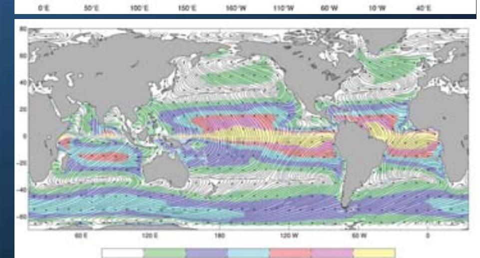
Mean geostrophic currents at sea surface



Mean Ekman currents at 15m depth



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hat' Not Certain?

What is the morphology (small-scale texture) of density of marine debris?

What is the role of local fronts?

Is their a practical proxy (SST, ocean color, etc.) that can be used assess debris distribution using satellite data?

Under what conditions debris from the North Pacific Convergence Zone is discharged on beaches/reefs?

Vertical structure of Ekman currents (how sensitive motion of debris to its vertical extent?)

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hat is Needed?

Near future (1-2 years)

- North Pacific data base of debris (types, life time, source areas)
- Data base of observed debris patches and events of its massive landing.
- Initial setup of operational system to hindcast debris distribution in the North Pacific. Setup of mechanisms for feedback and iterative improvement of the system.

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http://apdrc.soest.hawaii.edu

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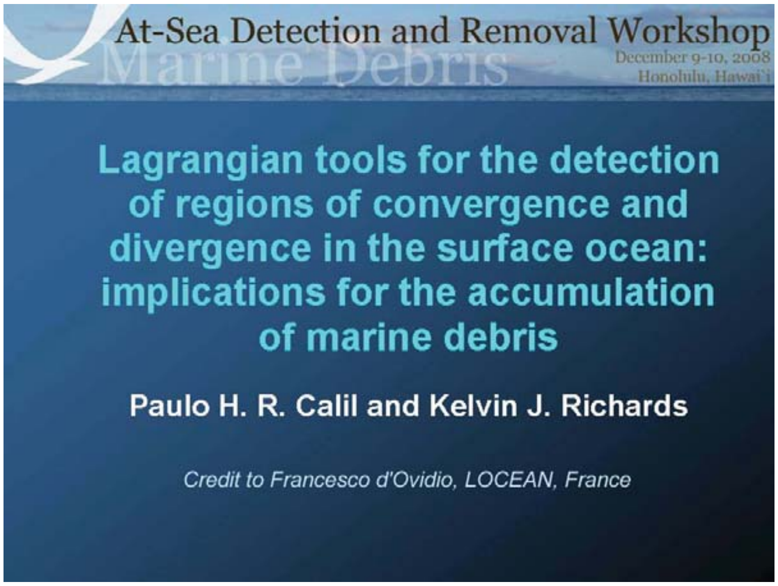
hat is Needed?

2-5 years

- Study ocean currents important for debris motion
  - Ekman spirals
  - frontal processes
  - others

> 5 years

- Design and deploy autonomous drifting stations collecting debris in open ocean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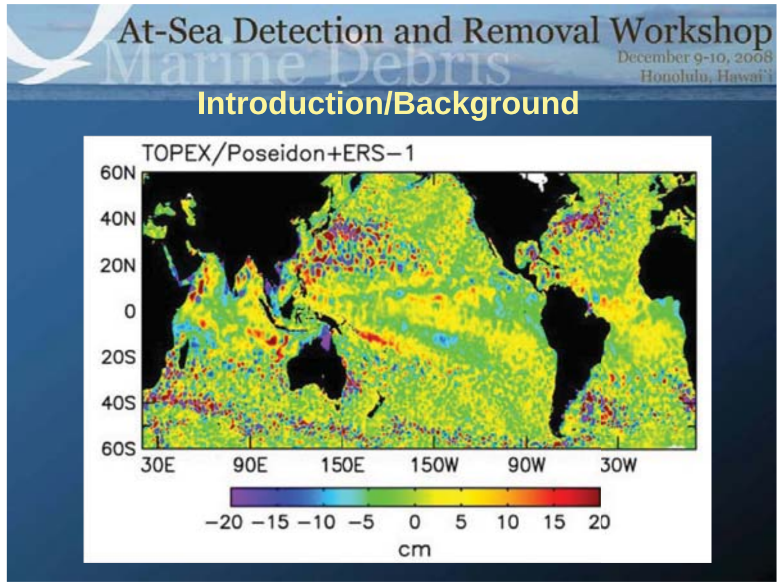
Lagrangian tools for the detection of regions of convergence and divergence in the surface ocean: implications for the accumulation of marine debris
Paulo H. R. Calil and Kelvin J. Richards
Credit to Francesco d'Ovidio, LOCEAN, France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Introduction/Background
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60S
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90E
150E
150W
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30W
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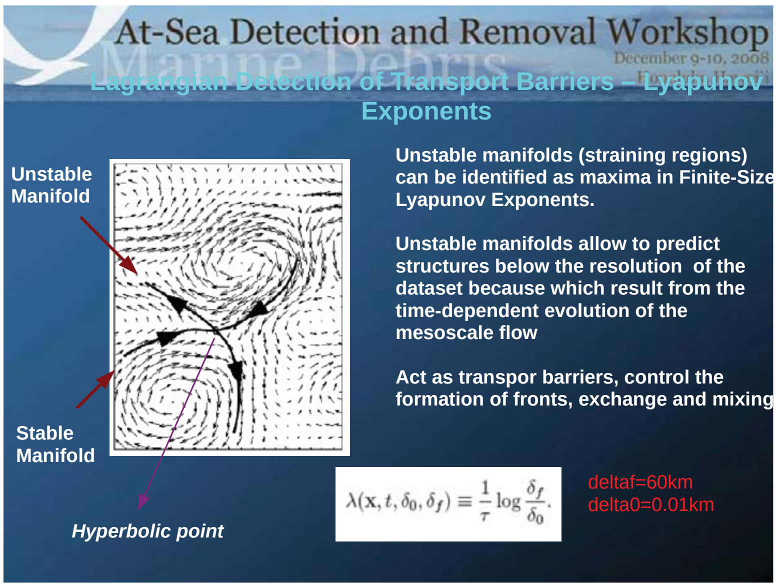
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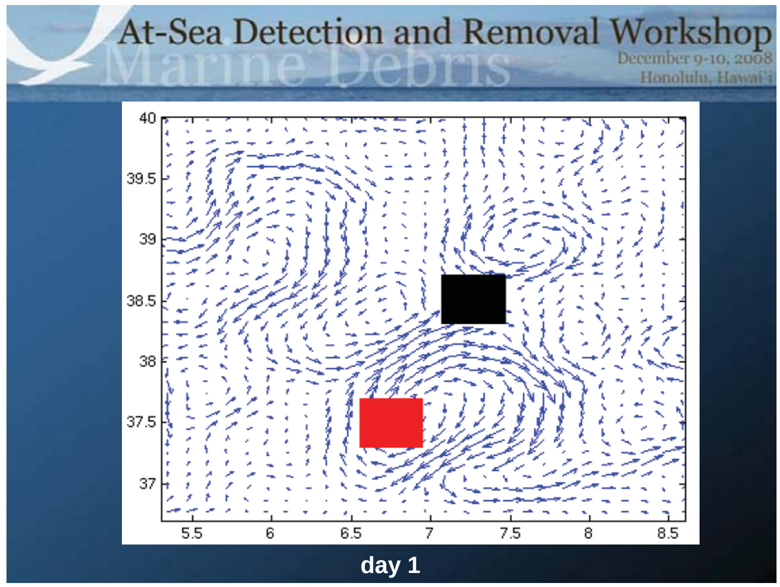
Lagrangian Detection of Transport Barriers – Lyapunov Exponents
Unstable Manifold
Stable Manifold
Hyperbolic point
Unstable manifolds (straining regions) can be identified as maxima in Finite-Size Lyapunov Exponents.
Unstable manifolds allow to predict structures below the resolution of the dataset because which result from the time-dependent evolution of the mesoscale flow
Act as transpor barriers, control the formation of fronts, exchange and mixing
$\lambda(\mathbf{x}, t, \delta_0, \delta_f) \equiv \frac{1}{\tau} \log \frac{\delta_f}{\delta_0}.$
deltaf=60km
delta0=0.01km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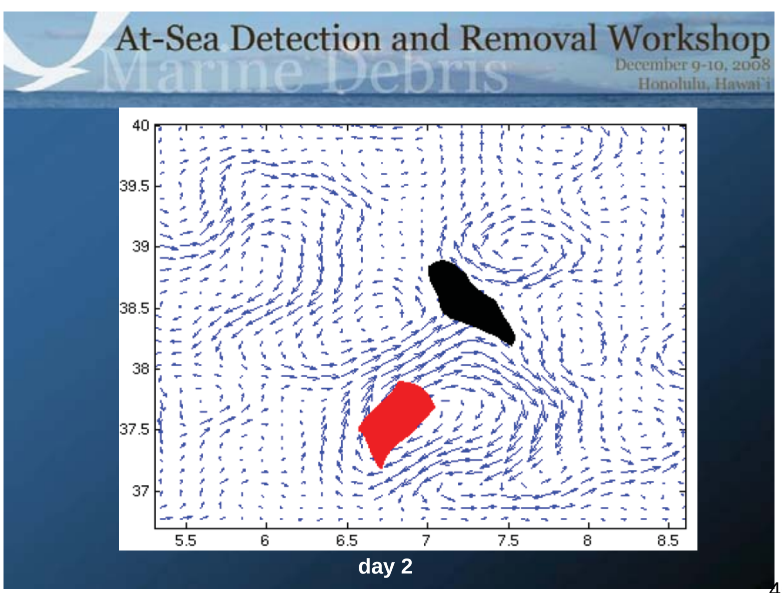
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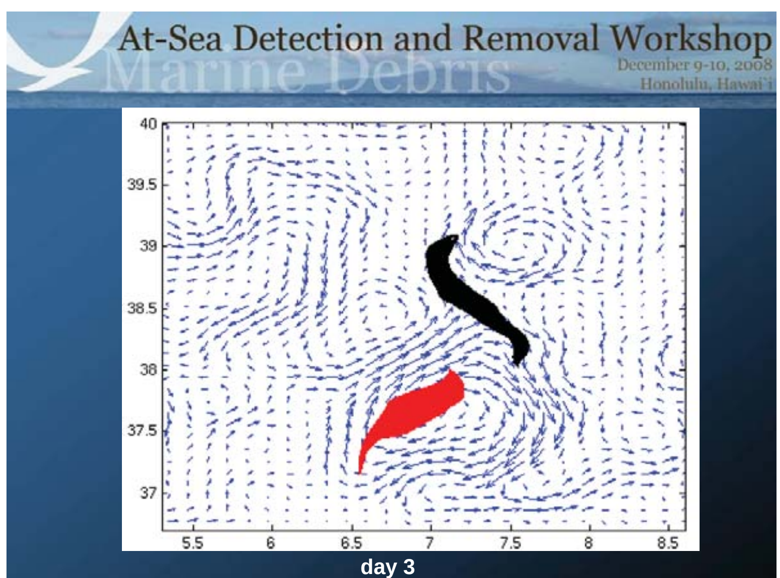
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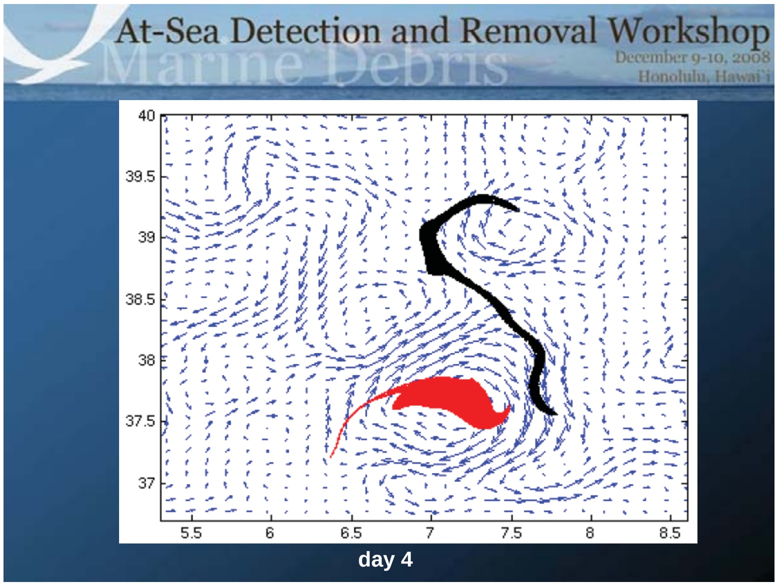
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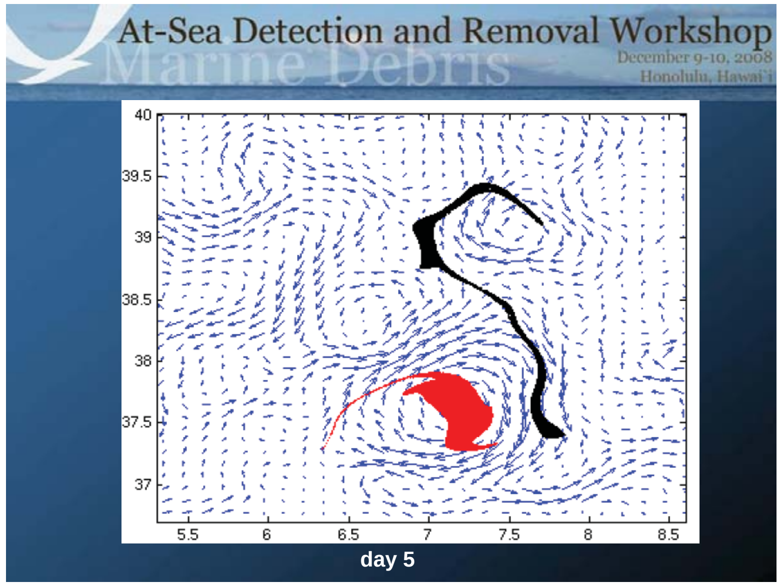
day 4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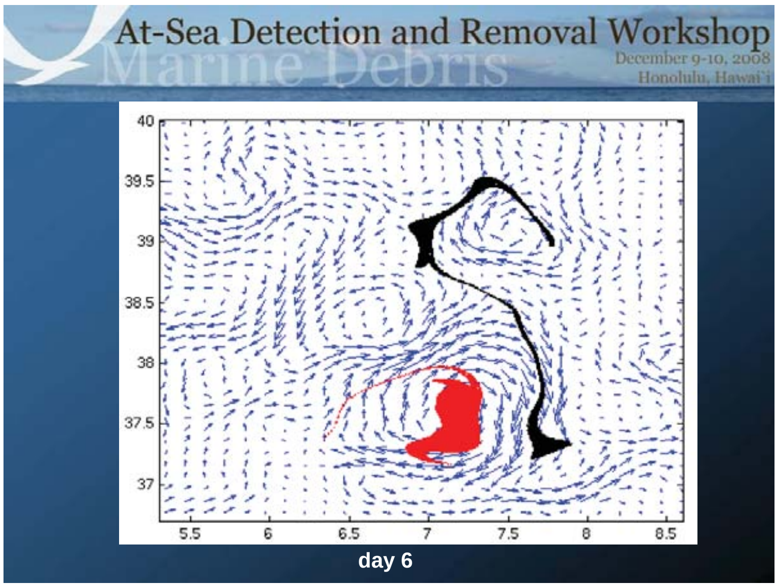
day 5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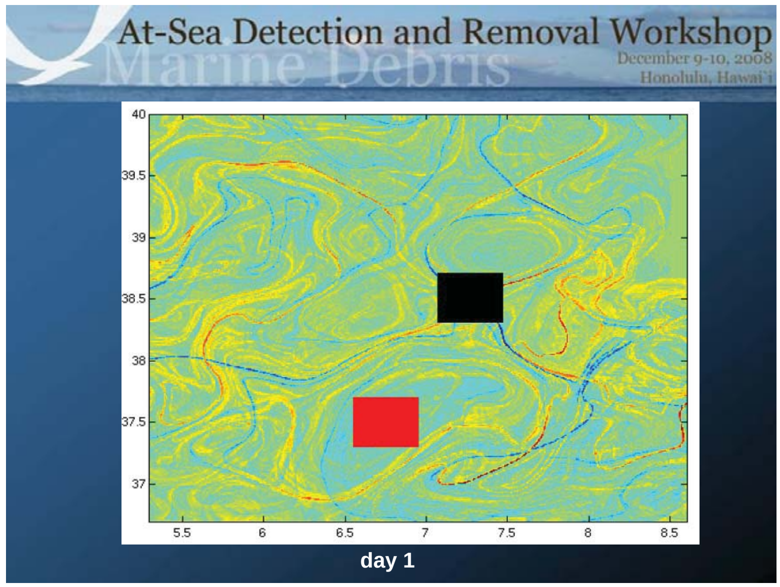
day 6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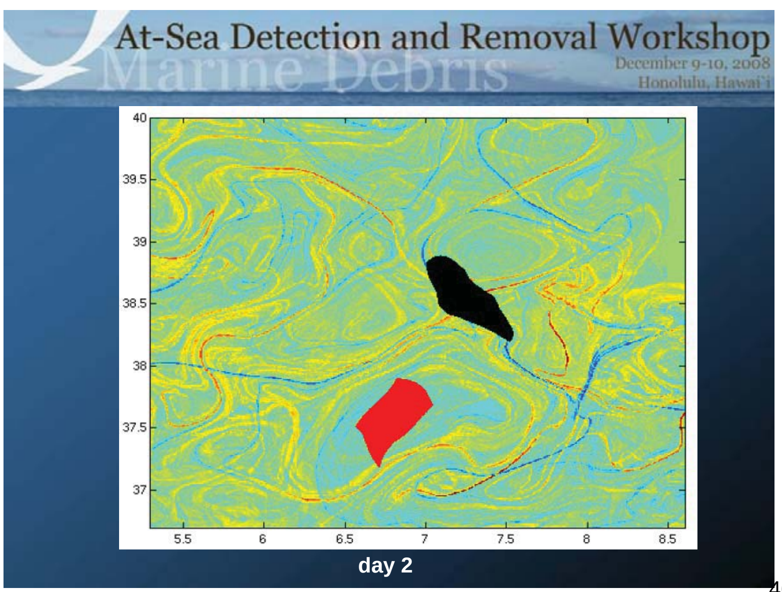
day 1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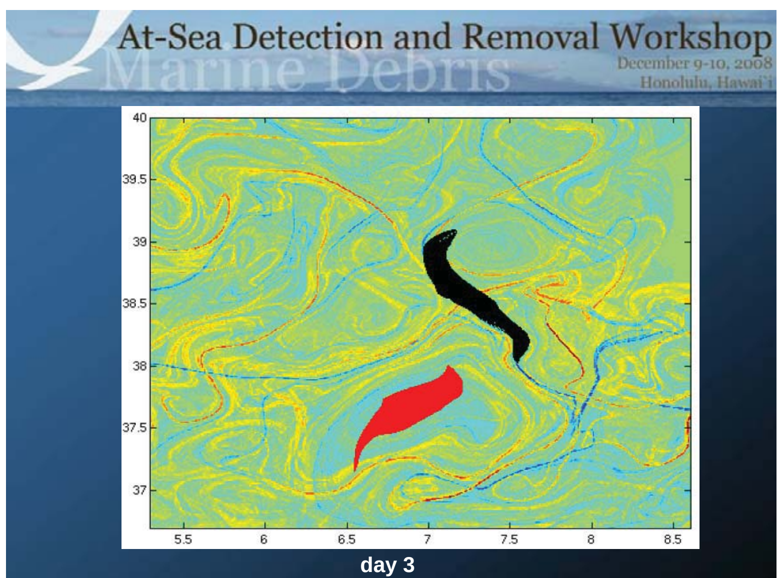
day 2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day 3

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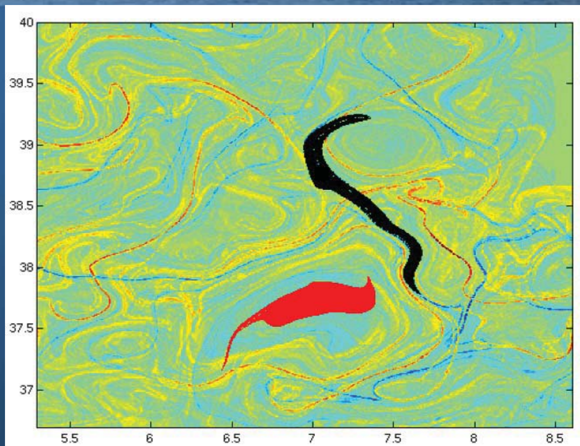

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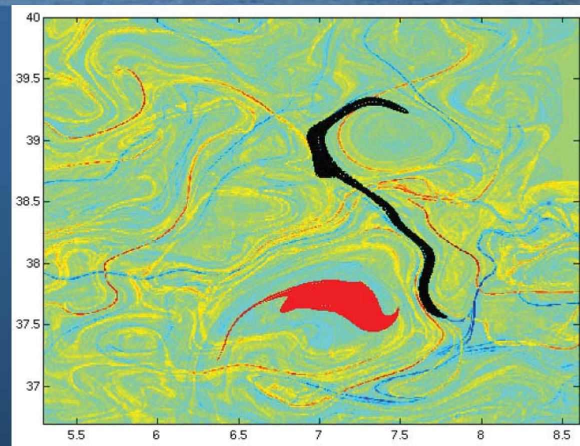

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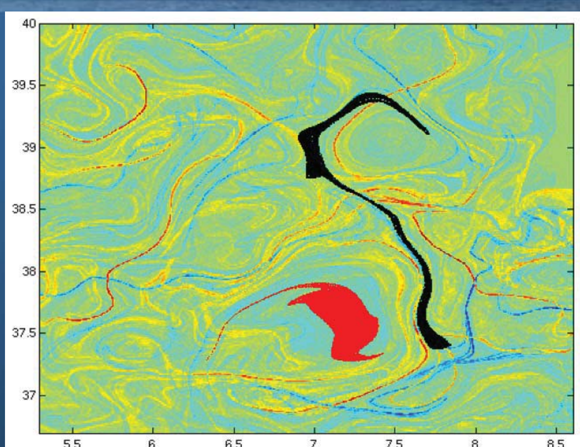

day 6

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What's known and very likely?

Unstable manifolds to some extent shape the distribution of surface buoyant materials by creating transport barriers and "sticky" surfaces in the flow field

Detection of unstable manifolds using satellite derived surface ocean velocities can be used to guide salvage operations to likely locations of debris

To our knowledge there has not been any systematic study of the relationship between the location of debris sightings and the underlying Lagrangian features of the ocean currents

Such a study would greatly increase our knowledge as to the utility of the flow descriptors described here in identifying likely locations of debris

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What's Not Certain?

How well satellite derived products detect the actual manifolds in the flow is an area of active research

Floating debris is subject to the actions of both the wind and the very near surface currents. To what extent this affects the trapping nature of unstable manifolds is unknown

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What is Needed?

Early actions

(i) comparison of past debris events with the detection of unstable manifolds, in order to understand how the flow field affects debris distribution
(ii) regional modeling studies to assess the space and timescales of debris dispersion and accumulation at the meso and submesoscale.

Mid- to long-term actions include

(i) adding prediction to our capabilities by using regional ocean observing systems
(ii) detailed modeling studies to investigate the impact of wind and very near surface currents
(iii) deliberate debris release experiments where the debris is tracked and the relationship to the underlying flow field assessed

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What's Very Likely?

- Bulleted list of items that we are fairly certain of, based on what we know
- Include additional information that might help us be more certain
- Keep in mind relation or applicability to marine debris

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Potential Sensors and Platforms

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Introduction/Background

Platforms

- A tool to carry the sensors necessary for identification, tracking and recovery of marine debris
- Increases spatial coverage over ship view
- Platforms to consider include:
  - Satellite
  - Manned Aircraft
  - Unmanned Aircraft
  - ???

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Introduction/Background

Platforms

- Satellite
  - Greatest spatial coverage
  - Helpful in identification of convergence areas
  - Able to track convergence areas
  - Not capable (yet) of actual debris identification
  - Limited to available satellites/sensors
  - Proved successful with GhostNet Project

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Introduction/Background

Platforms

- Manned Aircraft (land based)
  - Reduced spatial coverage
  - Requires greatest manpower effort (crew)
  - More flexible than satellite (adapting to weather and debris field movement)
  - Actual onboard visual decisions by crew
  - Limited range and loiter time
  - Few commercial aircraft can meet necessary requirements for range and payload

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Introduction/Background

Platforms

- Unmanned Aircraft (land based)
  - Reduced spatial coverage
  - More flexible than satellite (adapting to weather and debris field movement)
  - Limited range and loiter time
  - Few unmanned aircraft can meet necessary requirements for range and payload
  - Restricted by current FAA regulations

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Introduction/Background

Platforms

- Unmanned Aircraft (ship based)
  - Limited spatial coverage
  - Greatest flexibility for weather issues
  - Greatest loiter time near ship (multiple launches)
  - Limited in payload
  - Low risk exposure to personnel
  - Limited choice of aircraft
  - Restricted by current FAA regulations

Sensors

GhostNet Project tested a variety of satellite and airborne sensors in North Pacific and Gulf of Alaska waters

There are other potentially effective sensors but no known field data available for use with DFG

What's Known?

No single platform can perform all the necessary requirements for at-sea detection and tracking

Platform costs vary greatly depending on scope and type of debris detection required

UAS operations are overly restricted by the FAA

It is very hard to replace the human eye with a suite of airborne sensors and software

Limited aircraft (manned and unmanned) for marine survey on high seas

What's Known?

Sensors

Different sensors will be most effective under varying conditions including:

- Ocean region
- Sea state/wind
- Ambient light
- Water surface temp to air temp differential
- Turbidity
- Sun angle/sun glints

What's Known?

Sensors

Duplicity of sensors across different platforms is useful for ground truthing and resolution

Untested sensors include:

- Airborne SAR
- Hyperspectral
- Fluorescence
- ????

What's Known?

Sensors

Table 1 - Potential Sensors for Debris Detection Work

Sensor	Platform	Cost	Availability	Ocean Data Set
Ocean Color	All	Low	Yes	Yes
Ocean Temp	All	Low	Yes	Yes
RGB Video	All	Low	Yes	Yes
High Rez RGB	Airborne/UAS	Low	Yes	Yes
Thermal	All	Medium	Yes	Yes
Lidar	Airborne	High	Yes	Yes
SAR	Satellite/Airborne	High	Yes	Yes – Satellite Only
Hyper-spectral	Airborne/UAS	High	Yes(?)	No

What's Very Likely?

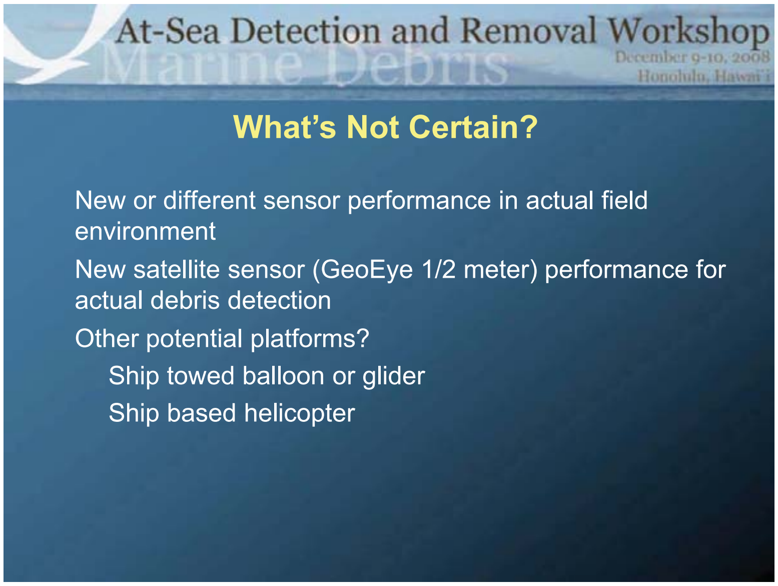
Sensor development will improve and cost will go down

Sensor size will get smaller allowing use on UAS

Better sensors than those currently tested will be available

UAS development will continue to improve rapidly in the next few years

FAA regulations will become friendlier to UAS operations, specifically on the high-seas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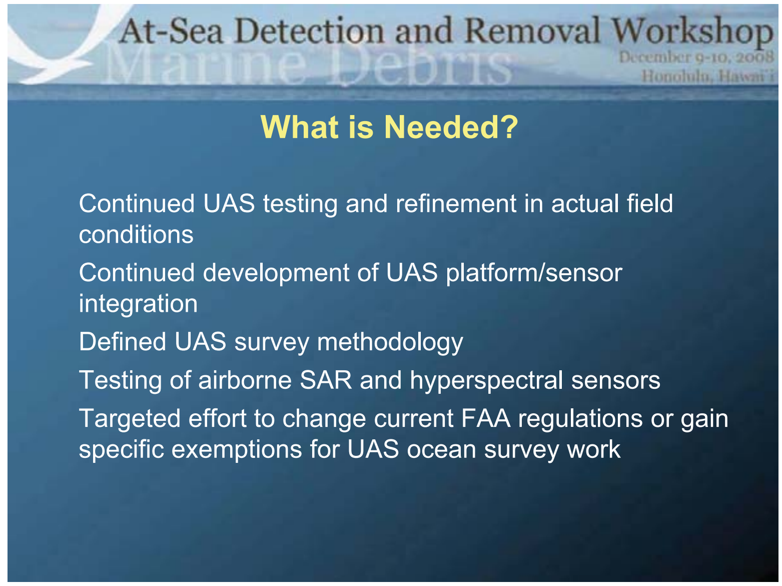
What's Not Certain?
New or different sensor performance in actual field environment
New satellite sensor (GeoEye 1/2 meter) performance for actual debris detection
Other potential platforms?
Ship towed balloon or glider
Ship based helicopter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What is Needed?
Continued UAS testing and refinement in actual field conditions
Continued development of UAS platform/sensor integration
Defined UAS survey methodology
Testing of airborne SAR and hyperspectral sensors
Targeted effort to change current FAA regulations or gain specific exemptions for UAS ocean survey work

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Tools to aid at-sea detection and removal efforts

Dave Foley, Rusty Brainard, William Pichel, and James Churnside

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Introduction/Background

- Evaluate opportunity cost for at-sea interdiction of large marine debris
  - Identify zones of debris accumulation
  - Develop methods for direct detection of debris at sea
  - Test system with in situ assets for actual removal
  - Use survey results to develop plans that optimize return upon a range of allocated resources
  - Provide options for operational implementation to managers

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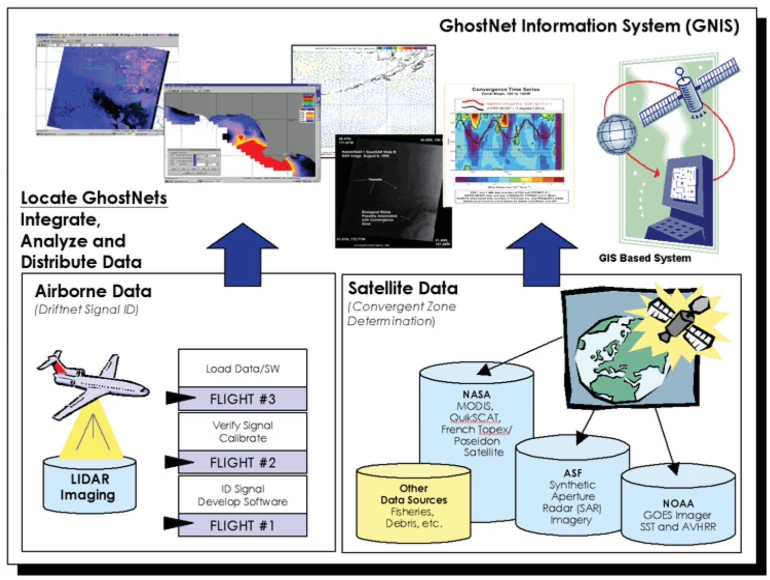
General Plan

- Successive Scaling
  - Identify zones of debris accumulation using ocean models or satellite data
  - Guide aircraft for direct identification and position
  - Direct recovery by ship already on station in general area



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What's Known?

- Debris continues to accumulate on the NWHI at a fairly steady rate
- The density of debris in the vicinity of the winter-time TZCF is significantly higher than that of surrounding waters
- The TZCF demonstrates significant seasonal and interannual variation that provides a mechanism for years of particularly heavy deposition on the NWHI

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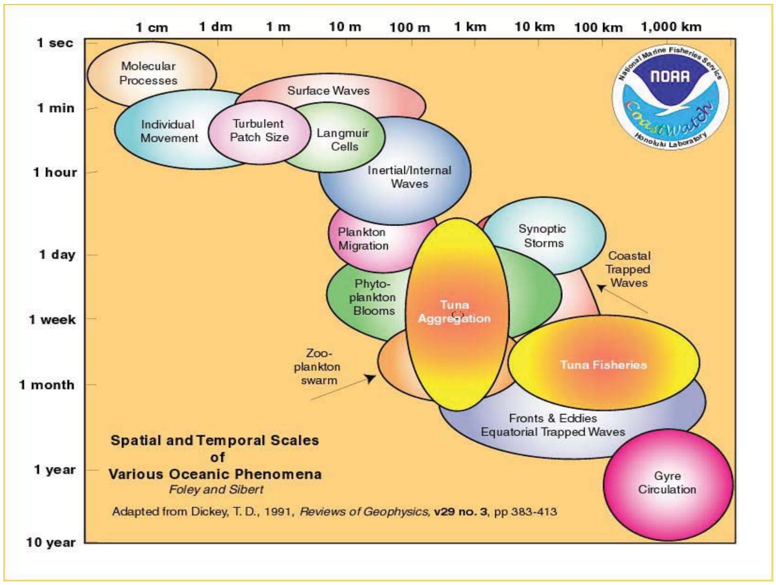
What's Very Likely?

- Wide range of scales must be resolved by models and direct observations
  - Mesoscale (100 km, 3-7 days)
  - Seasonal (1000 km, 1-3 months)
  - Interannual (10000 km, > 3 years)



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s Not Certain?

- Sources
  - Points of origin
  - Numbers introduced at those points
  - Temporal changes in rates
- Transport models
  - OSCURS
  - OGCM
  - Surface drift
  - Other (?)

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What is Needed?

- 1-2 year plan
  - Develop transport models to produce debris density maps under a variety of seeding scenarios
  - Develop methods for direct at-sea detection using a variety of remote-sensing techniques
    - Satellite
    - Piloted aircraft
    - Autonomous aircraft
- 2-5 year plan
  - Integrate two items above to produce a sampling plan to conduct a census of the North Pacific

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What is Needed? (continued)

- 2-5 year plan (continued)
  - Prepare a variety of schemes for operational application
- Beyond 5 years
  - Execute supported operational schemes

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History of the GhostNet Project

William Pichel
James Churnside
Rusty Brainard
Tim Veenstra
Dave Foley

Derelict Net in the Eastern Garbage Patch – Courtesy Charles Moore

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GhostNet Background – Origins

Origin:
Alaska Needs Workshop: Airborne and Space-based Remote Sensing Technologies - sponsored by NASA and State of Alaska – May 2001

Proposal:
"High Seas Driftnet Detection and Tracking in the North Pacific Waters Using Satellite and Airborne Remote Sensing."

Focus:
Gulf of Alaska and Bering Sea
North Pacific Subtropical Convergence Zone

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GhostNet Background – Participants

Original Proposal Participants:
Tim Veenstra: PI Airborne Technologies, Inc.
James Churnside NOAA/ESRL
William Pichel NOAA/NESDIS
Dale Kiefer - Univ. of Southern California
Evelyn Brown Univ. of Alaska, Anchorage
Nettie LaBelle-Hamer Alaska Satellite Facility, Univ. of Alaska, Fairbanks
Julie Stinson Business Integration Group
Eric Rogers Scientific Fisheries

Additional GhostNet Team Members
Dave Foley NOAA/NMFS
Rusty Brainard and Kevin Wong – NOAA/NMFS
Kris McElwee and Carey Morishige NOAA Marine Debris Program
Simeon Ogle – Univ. of Southern California
Elena Arabini, Karen Friedman, Christopher Jackson NOAA/NESDIS
Jeremy Nicoll, Don Atwood Alaska Satellite Facility
Now many others …

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GhostNet Background – Components

Components

1. Circulation models
2. GhostNet drifting buoy
3. Ocean GIS
4. Satellite Remote Sensing
5. Aircraft Remote Sensing
6. Aerial Debris Surveys
7. GhostNet Unmanned Aircraft System (UAS)
8. Ship/UAS Surveys

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GhostNet Field Programs - What We've Learned

GhostNet Field Programs
1. Gulf of Alaska 2003
2. North Pacific Subtropical Convergence 2005
3. Hawaii High-Resolution Satellite Data Test 2006
4. GhostNet UAS Sea Trials 2007/2008
5. North Pacific Subtropical Convergence 2008

First GhostNet Survey


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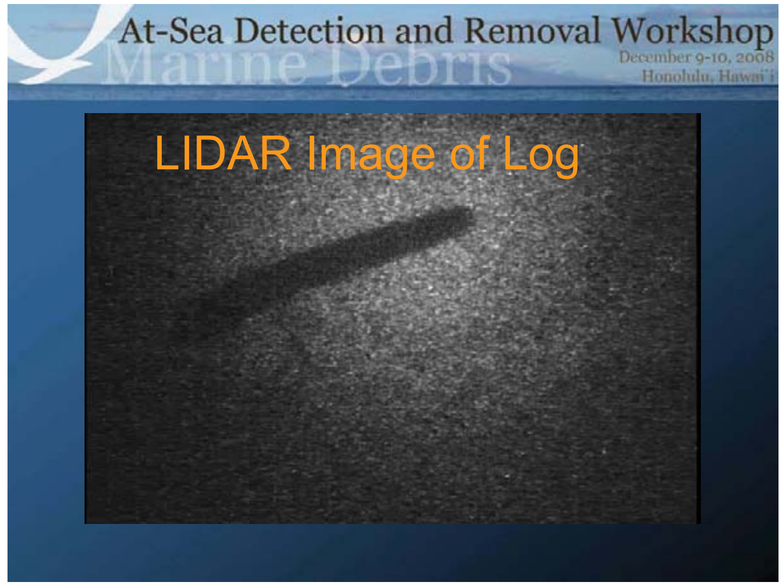
GhostNet Aircraft Instruments
• Infrared Imager
• Visible RGB Camera
• Green laser (532 nm) imaging LIDAR
• Computer with anomaly detection
• Visual search
• Infrared Radiometer - SST
• MicroSas Optical Sensor - OCR-507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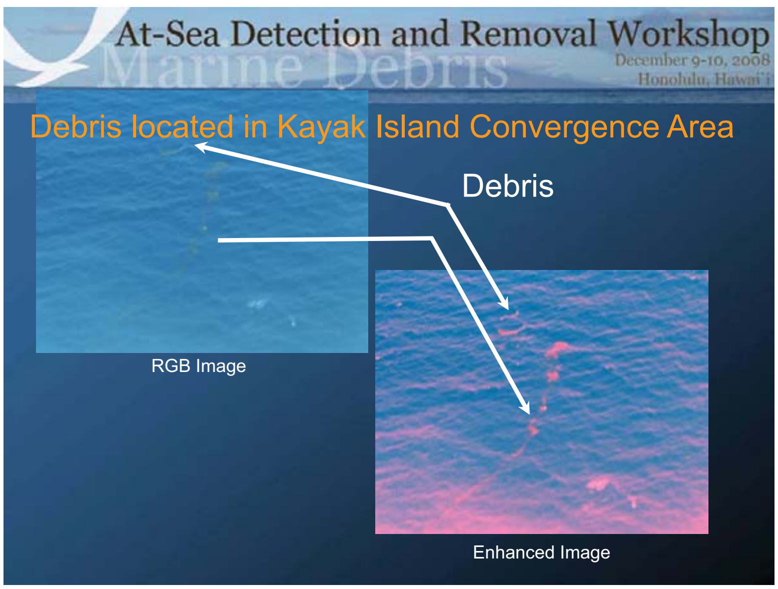
LIDAR Image of Log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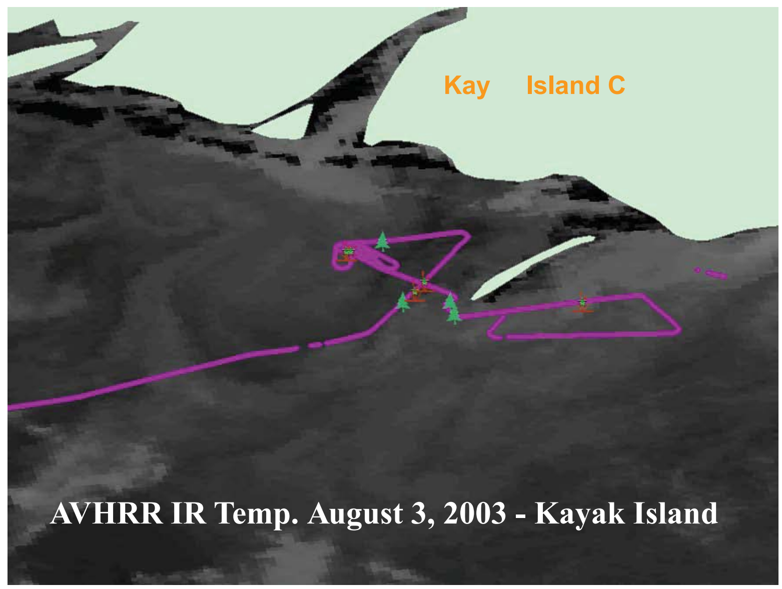
Debris located in Kayak Island Convergence Area
Debris
RGB Image
Enhanced Image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Island C
AVHRR IR Temp. August 3, 2003 - Kayak Island


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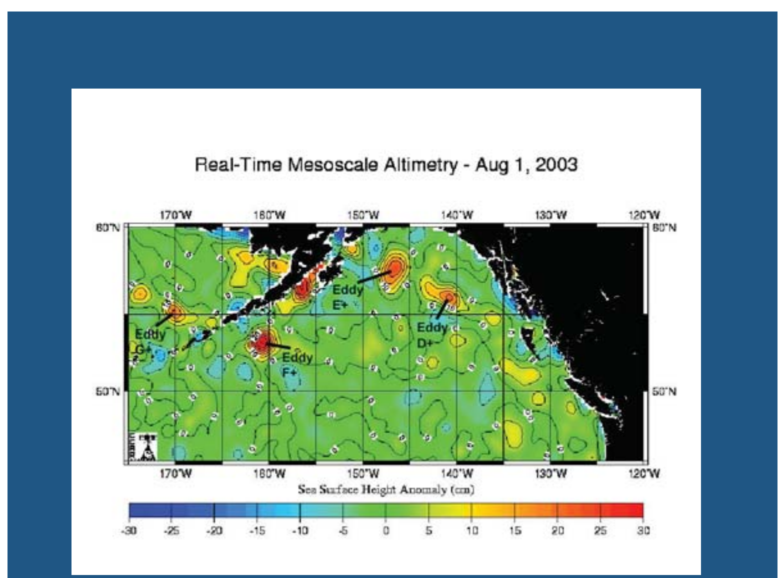
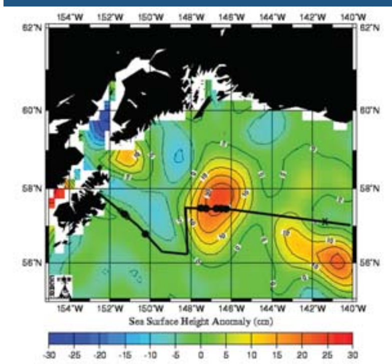
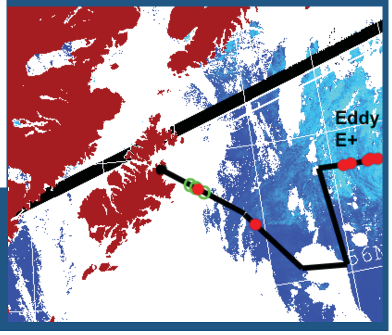

Real-Time Mesoscale Altimetry - Aug 1, 2003
Sea Surface Height Anomaly (cm)

GhostNet Flight Track and Debris Sightings Eddy E+ (August 1, 2003)

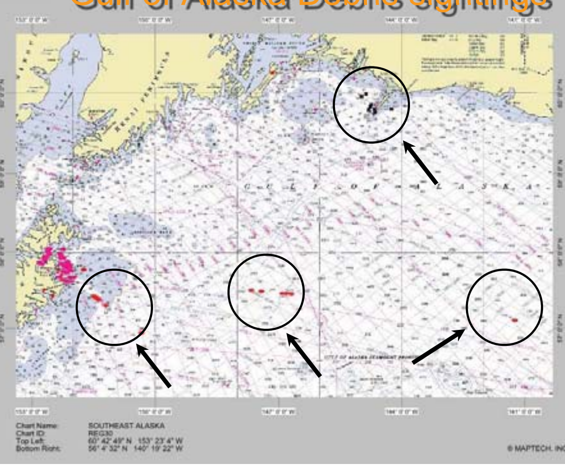


Near Real-time
Sea Surface Anomaly Map
of Eddy E+
August 1, 2003
(Map created by Colorado Center for Astrodynamics Research, Univ. of Colorado)

NOAA CoastWatch AVHRR SST
Image of Eddy E+ July 23, 2003



Gulf of Alaska Debris sightings



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ery Likely?

Debris in Gulf of Alaska
- Debris found mostly in convergence areas, frontal areas, eddies
- Not much debris in central Gulf of Alaska

Satellite Data:
- Altimeter data key to mapping eddies
- Single-orbit, full-resolution chlorophyll and SST imagery are the most useful data for mapping eddies under cloud-free conditions
- SAR imagery useful under cloudy conditions

Aircraft Data:
- Anomaly detection software is essential for in-flight analysis
- Thermal IR is not effective for debris detection.
- Good communications is critical for flight planning.
- Real-time satellite data integrated with aircraft GPS would be helpful.
- For LIDAR to be effective, swath width must be much larger.

GhostNet Second Survey March 16 ril 10, 2005

NOAA P3 Flights from Hawaii to the North Pacific Subtropical Convergence Zone

Flight 1 – March 18
Flight 2 – March 27
Flight 3 – March 29
Flight 4 – April 3

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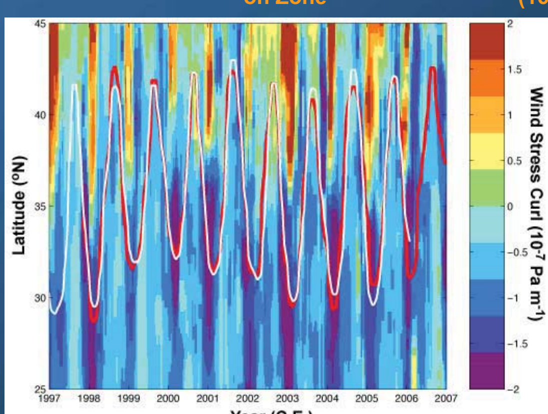
on Zone (160-180W)



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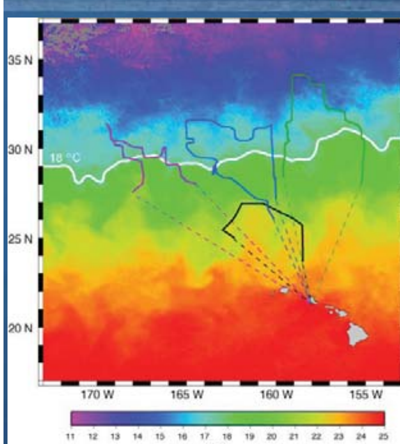

31, 2005

Black: 18,
olet: 27,
Green: March 29,
Blue: 3, 2005

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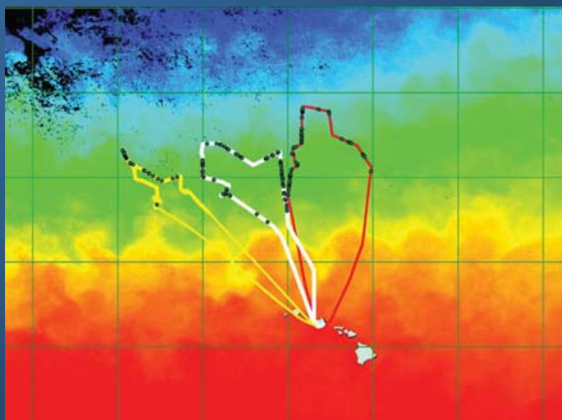

ngs on GOES SST 4-Day Composi

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ch-April 2005
of D

pe of			4	OTAL
Buoys	24			68
	29	86	158	27
		560	6	394
		9		
	421			7
		43	59	
TOTAL	79	7	875	885

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Bi	68	47	53	168
Whal			15	16
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TO	70	50	272	392

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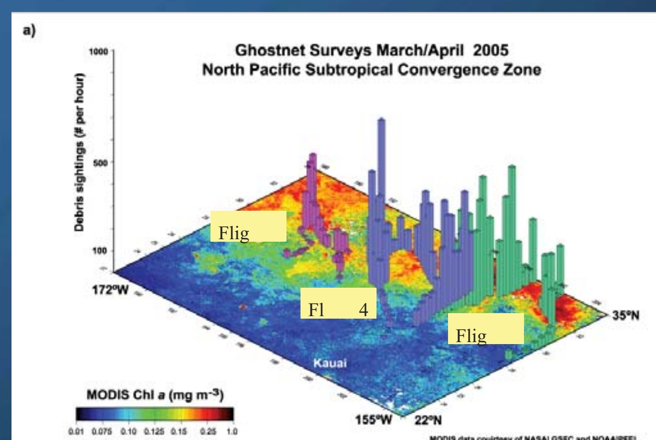

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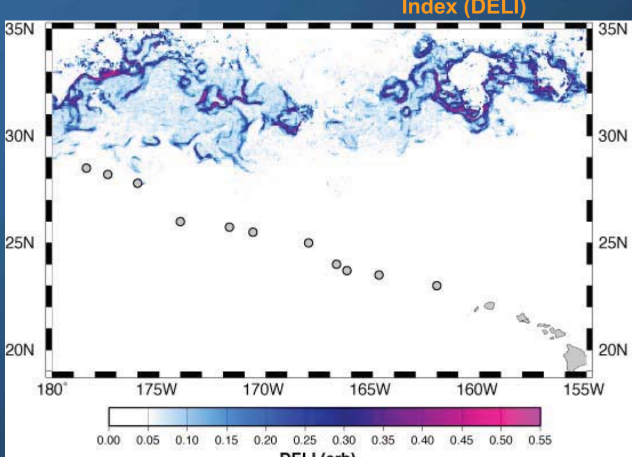
Index (DELI)



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ery Likely?

Zone

- Nets were common in North Pacific Convergence Zone, but floats are most common form of debris
- Debris was found concentrated just north of the location of the Transition Zone Chlorophyll Front at this time of year
- Visual observations are an efficient means of accurately spotting marine debris from aircraft.
- Satellite-derived chlorophyll and SST maps and debris observations can be used to derive a Debris Likelihood Index which may be useful for indicating the geographic regions that can be most efficiently surveyed for marine debris; the usefulness of this Index needs to be assessed.
- Many animals were sighted in debris areas.

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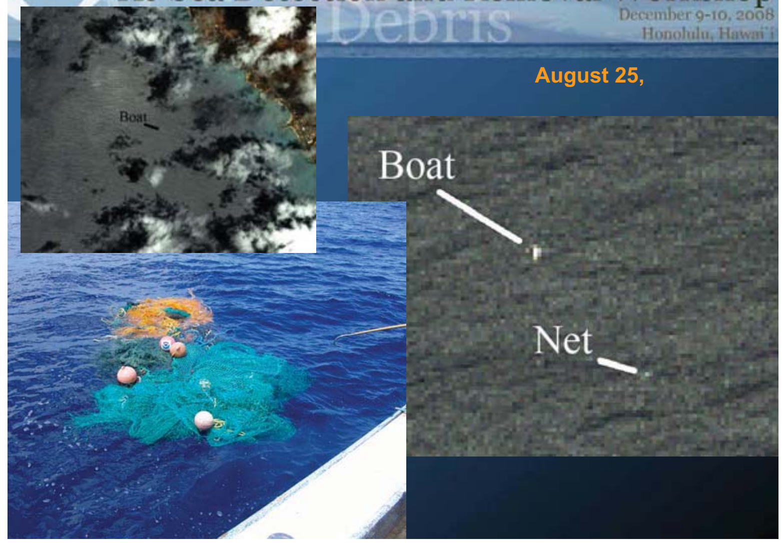

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s Not Certain?

- Are there areas in the Bering Sea with substantial debris? Where are they?
- Is there still a lot of debris just south of the Aleutians as reported by Mio et al., 1990.
- How much debris is generated by the various fisheries in the Bering Sea (U.S. and Russian)? What is the fate of this debris?
- Will a combination of information on fishing activity and effort and accurate oceanic and near shore circulation modeling allow accurate predictions of beach debris accumulation?
- What is the debris situation in the Arctic Ocean and on its shores? How can GhostNet best connect with the NOAA thrust in the Arctic?
- What is the rate of marine debris deposition on representative shorelines of Alaska? Where are the hot spots?
- Are eddies really hot spots for MD presence?
- Are there oceanic convergence areas in the Gulf of Alaska or Bering Sea where MD aggregates in the open ocean? Is there a seasonal cycle if such convergence occurs?

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s Not Certain?

Cont).

- Where does the MD that washes up on the Pribilofs Islands come from and is it washed ashore seasonally? Do St. Paul Island and St. George Island have similar marine debris deposition rates?
- What is the impact of MD on marine mammals in Alaska? On salmon?
- Can oceanographic models or coupled ocean/atmosphere models be used to predict where MD will collect on shore and where the hot spots are?
- What are the best models to use? How can they be validated? How can they be used for oil spill trajectory forecasts?
- What are the MD objectives and priorities of NOAA in Alaska, the State of Alaska, and NGO conservation groups in Alaska? How does GhostNet fit into these priorities?

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s Not Certain?

- How much MD is present? How distributed?
- How does distribution change with time?
- Is total amount of MD increasing or decreasing and at what rate?
- What happens to the MD?
- What remains in summer in the area of the wintertime convergence?
- How much macro debris (especially derelict fishing nets) is in the eastern- and western "garbage patches?"
- What is the "life cycle" of MD in the garbage patches?
- What is the best strategy to survey the MD in the North Pacific?
- What is the best way to use a UAS and ship together to survey MD?
- What UAS capabilities should be the ultimate goal for GhostNet?
- Will the new higher-resolution satellite sensors do a better job of spotting debris from space?

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What is Needed?

he near future (1-2 years)

Continue development and testing of UAS
Develop a circulation modeling capability for GhostNet
Validate the circulation model with archived buoy drift information and with GhostNet buoy deployments
Test satellite detection of nets with the new GeoEye-1 satellite multi-spectral data
Develop a practical ship/UAS survey strategy and test it.

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What is Needed?

Survey the North Pacific to estimate the amount of debris and its distribution.
Survey the garbage patches to determine amount and distribution of debris.
Develop a post-hurricane marine debris survey strategy and test it.
Implement an operational at-sea marine debris detection and recovery program.

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Gho P ojec : http://www.highseasghost.net/index_new.html

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Ghos Da De P ts:
ftp://orpheus.pfel.noaa.gov/outgoing/dfoley/pifsc/cred/deli/
http://www.star.nesdis.noaa.gov/sod/mecb/sar/gnet/ghostnet07.html

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http://marinedebris.noaa.gov/projects/atsea_cruise.html
http://trekme.com/oceandebris/

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Closing Remarks

Robbie Hood

NOAA UAS Program Director

robbie.hood@noaa.gov

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Initial Impressions

- Importance and magnitude of the Marine Debris problem is significant
- Multi-disciplinary expertise addressing the issue is substantial
- Importance of collaborations and strategic planning is understood

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Learning Process Underway

- Needed to start somewhere
- Documenting lessons learned
- Identifying requirements and systems approach to focus future research and development on feasible solutions
- Defining metrics, milestones, and levels of success

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Soapbox

- Actively use strategic planning to focus community efforts and progress toward milestones
- Define observational requirements early and modify, if necessary, as R&D progresses
- Do not define observational requirements by sensor or platform capabilities
- Define minimum success criteria beforehand and manage stakeholder expectations
- Treat information technology as an equal to sensor/platform technology for each successful solution

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NOAA UAS History and Strategy

Established NOAA's UAS effort as a "Major Project" (FY05)

Began conducting small field demonstrations (FY05)

Developed 10-year UAS Project plan through NOAA's PPBES process

FY08 Funding start (in President's Budget, House and Senate Marks)

Established a Testbed approach for implementation (FY07)
- *Phase I: Test and evaluate possible applications (FY08-10)*
- *Phase II: Acquire and operate a first set of major UAS (FY11-13)*
- *Phase III: Expand to global coverage (FY14 and beyond)*

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NOAA UAS FY09-FY10 Priorities

- *UAS recommendations for NOAA management*
  - *Collection of observing requirements across NOAA Line Offices and mission application areas*
  - *UAS acquisition and operation trade studies*
  - *Go / No Go acquisition recommendation by FY10*
- *R & D Investments*
  - *Platform evaluations*
  - *Test bed demonstrations*
  - *Sensor development*
  - *Observing System Experiments (OSE) and Observing System Simulation Experiments*


Unmanned Aircraft Systems
UAS Test Beds
Arctic
Pacific
Hurricanes
uas.noaa.gov

APPENDIX V. Discussion Notes

Tiered approach

- No single platform can perform all necessary steps from detection to removal.
- Having a short-range detection mechanism on a removal ship is critical to pinpoint areas of high density. At this point remote sensing and modeling give too large a range.
- We need to reduce the search area. This is broken down into two questions:
  - Can DFG be parameterized to allow for tracking and modeling of debris movement?
  - What is the optimum system for reducing the search area?

Strategies for selecting detection technology (presented by three groups)

Strategy A:

1. Develop parameters that describe DFG for modeling and model validation.
2. Develop parameters that describe DFG for remote sensing detection.
3. Stratify entire search area using satellite imagery and models.
4. Validate strata using a statistical sample.

Strategy B:

1. Look at the life cycle and distribution of DFG. Oceanography has a role in this, so that should be considered.
2. Look at the technology and find the best sensor suite to detect and track DFG. Oceanography will also influence the choice or development of the best sensor suite. The sensor suite breaks down into these three action items:
   - Evaluate existing data.
   - Do field tests.
   - Work on open development.

Strategy C:

1. Decide size of DFG of interest (min, max).
2. Collect examples of DFG.
3. Deliver variety of examples of DFG/sheeting to sensor team.
4. Identify candidate sensor suite against components by DFG.
5. Run preliminary tests in simulated environment.
6. Use/improve circulation models to target likely environments.
7. Profile environment (include seasonal, interannual variability).
8. Determine potential platforms against defined environment.
9. Systems analysis of down-selected options: sensor + platform + bounded environment.
10. Test-off/fly-off/comparison matrix/system selection.

Unknowns

- What is the shape of DFG in the open ocean? The shape of debris will change its trajectory. For modeling, we need to come up with a general shape.
- Vertical extent of DFG in the water column is very important. It is important to define the general characteristics of debris for modeling efforts.
- Is neutrally buoyant debris affected by downwelling? Does it subduct? How do fouling organisms affect density of nets? We need a better sense of vertical movement. Density of nets might change with temperature; there might be a temperature barrier/point along the water column where nets sink and no longer float.
- We need a better understanding of the life cycle and distribution of DFG.
- How does DFG move with/within the zones (e.g., STCZ)? Smaller questions to resolve to answer the bigger question:
    - How important are zones and how do we measure them?
    - What is the degree of predictability of debris distribution at oceanic fronts in the North Pacific?
    - How should we survey and map; how good are the maps?
    - What is the total abundance of DFG in the N. Pacific and how does it change over time?
    - What is the large-scale life cycle of debris sources and sinks?
    - What is the behavior (movements) and fate of DFG after it enters the ocean?
    - Is tagging effective?
- Do we know the strength of small-scale convergence? What would it take to get stuff out of a convergence zone?

Cost/Importance/Scale of problem

- How much does it cost? How much money is available?
- What are the ecological considerations? (for prioritization and to ensure methods don't have negative impact)
- What is the cost of doing nothing? What are the start-up costs?
- One thing before we get started is to show how important it is, to show the cost of not doing something.

Strategies:

- Is it worth it to develop a research/monitoring plan and associated costs?
- Develop and validate a mass balance for DFG (scale the problem):
    - Identify sources
    - Identify sinks
    - Quantify "standing stock"
    - Partition pathways
- Estimate costs of impacts.

- What is the best technology for low-cost debris collection from large areas (e.g., autonomous platforms in STCZ)?

- How do economic impacts and liability concerns lead to political interest and public awareness of DFG?
- What are the economic considerations of DFG mitigation (emphasis on detection and removal)?
- What are the economics of DFG impacts and recovery strategies?
- To what extent is DFG a hazard to navigation?
- One possibility is to look internationally at the manufacture and sales of fishing gear. If we know those figures and the amount discarded on land, we might be able to estimate the volume that's being lost at sea.
- Suggestion of developing a "road show" and an elevator speech to get attention for the program and enlist partners.

APPENDIX VI. Gaps Summary

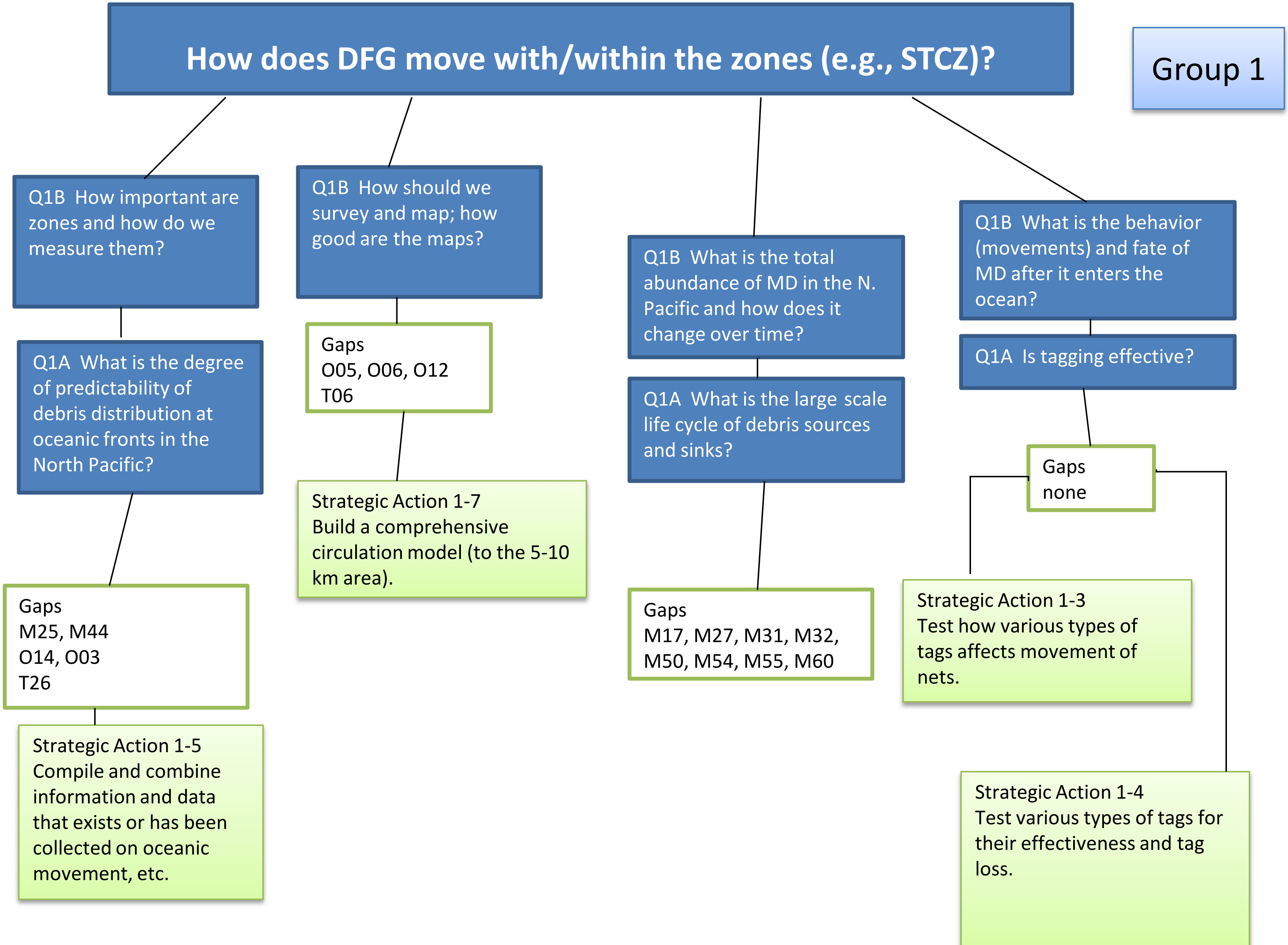
Derelict Fishing Gear Characteristics	
M01.	What are the ecological impacts of DFG on the open ocean?
M02.	What are the navigational impacts of DFG on the open ocean?
M03.	What is the cost of large-scale at sea DFG removal?
M04.	What is the accumulation rate of DFG on the Main Hawaiian Islands?
M05.	What is the cost (both economic and ecological) of DFG removal at sea compared to removal from reefs/habitats?
M06.	What is the effect of wind on net movement?
M07.	What is the effect of tagging devices on net movement?
M08.	What is the age of nets and lines in large aggregations?
M09.	What is the photodegradation rate of different types of line?
M10.	What is the average size and weight of aggregations found at-sea?
M11.	What is the average size and weight of aggregations found on reefs?
M12.	What is the level of funding for future reef removal efforts?
M13.	How do we determine whether nets that are on the reef need to be removed?
M14.	What is the timeline of benthic community recovery after nets have been removed?
M15.	What are the effects of nets in high and low energy habitats?
M16.	How much DFG is present in the North Pacific?
M17.	How is DFG distributed in the North Pacific?
M18.	How does DFG distribution change with time in the North Pacific?
M19.	Is the total amount of DFG in the ocean increasing or decreasing and at what is the rate?
M20.	What is the fate of the DFG that is in the ocean?
M21.	What is the "life cycle" of DFG in the so-called garbage patches?
M22.	How does the density of DFG debris vary from east to west along N. Pacific STCZ?
M23.	Would at-sea marine debris removal significantly decrease the amount of debris that accumulates in the NWHI?
M24.	What is the morphology of the MD patch in the North Pacific?
M25.	How heterogeneous is the density of the MD patch?
M26.	What are the characteristics of individual clusters within the MD patch?
M27.	What is the vertical distribution of a net in the water column?
M28.	What is the timing and location of introduction of MD into the environment?
M29.	What is the number of nets that are currently circulating the ocean?
M30.	If a net is located in a convergence zone, does it stay there?
M31.	What percentage of nets end up on shore?
M32.	Is the rate of lost nets increasing or decreasing?
M33.	What is the economic impact of marine debris to navigation, fisheries and ecosystems?
M34.	How much DFG needs to be removed to mitigate economic impacts (e.g., for incentive program feasibility)?
M35.	How do we have an incentives program and avoid "freight-for-hire" and liability concerns?
M36.	What incentives can be established to maintain/ increase participation from the longliners at Pier 38?

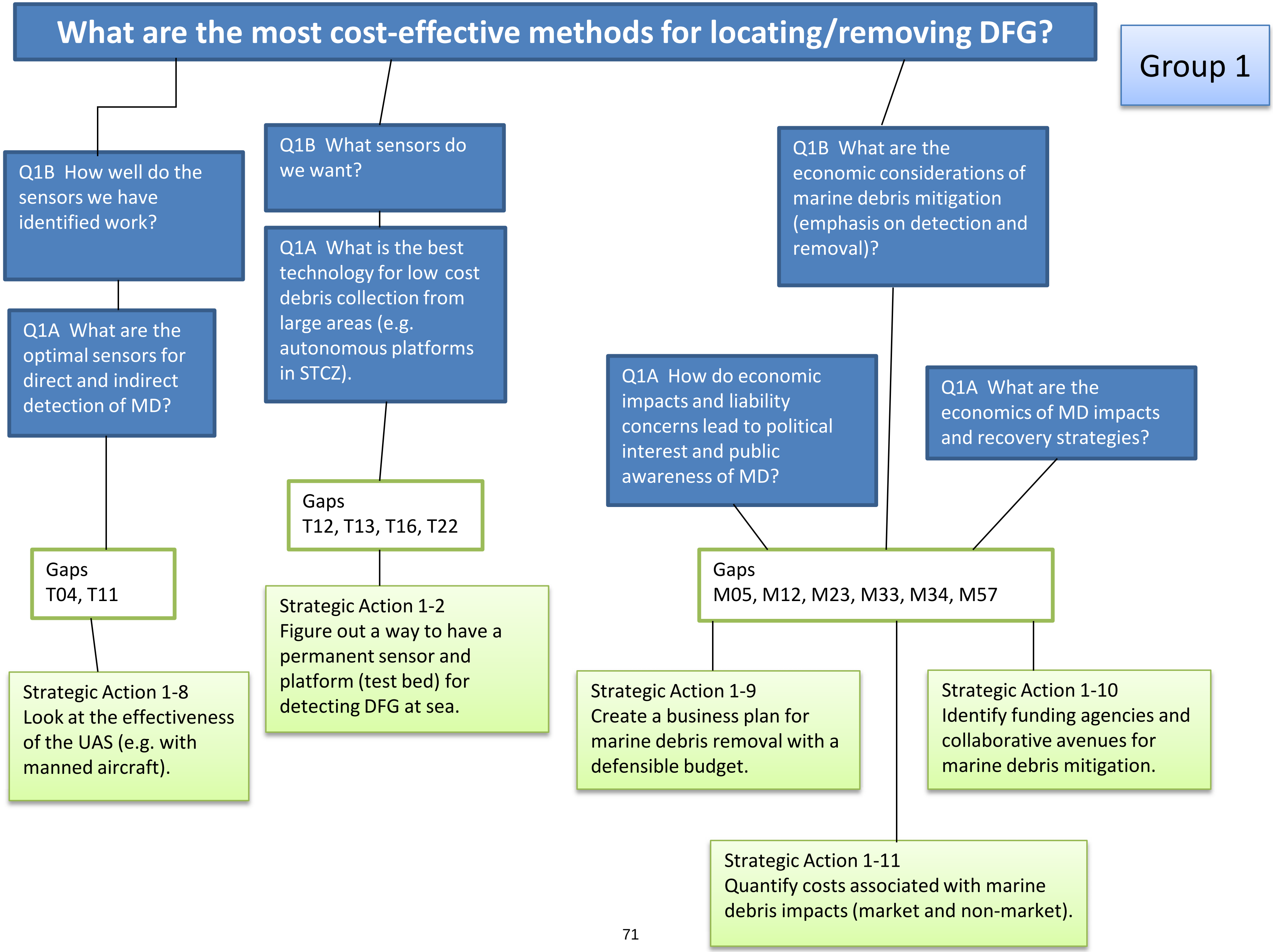
M37.	How can we utilize longline fishing boats to tag/mark derelict fishing gear?
M38.	What is the political will and commitment to establish large-scale measures?
M39.	What are concrete estimates of the interaction of MD with fisheries, protected species, sea birds, beach users, the shipping industry, and marine navigation?
M40.	What strategies could be used to develop profitable products from MD?
M41.	How do we forecast the direction or speed of a net/DFG?
M42.	Do convergence zones contain the majority of the nets/DFG?
M43.	Do tagging buoys separate from nets? If so, are we tracking the buoy and not the net?
M44.	How do we gather data for identifying and tracking convergent areas in sub-optimal weather conditions?
M45.	How do we identify and track sub-surface nets?
M46.	How do we sustainably fund a monetary incentives program?
M47.	How will fishermen locate marine debris at sea?
M48.	How will fishermen safely remove debris at sea? And in the quantities sufficient to mitigate impacts?
M49.	Is the behavior of marine debris based on debris vertical size and shape?
M50.	What is the distribution of parameters (e.g., size, shape, buoyancy) of marine debris?
M51.	What is the distribution of marine debris in the N. Pacific? (including documented events of debris landing on beaches)
M52.	What is the lifetime of marine debris? (degradation rate?)
M53.	How much DFG is currently present in pelagic and island-associated environments?
M54.	How much DFG is added each year to these “stocks,” and from what fisheries and locations?
M55.	How much and at what rate is DFG is being deposited in high-risk areas (e.g., the Hawaiian Islands)?
M56.	How much DFG is modified each year through sinking or degradation into pieces too small to entangle?
M57.	How many individuals of threatened and endangered species are killed each year at sea as a result of DFG?
M58.	How much volunteer time and in-kind services are provided by beach cleanups and at-sea removal efforts?
M59.	Do micro- and meso-debris floating near the ocean surface serve as a proxy indicator for accumulation zones of DFG?
M60.	What is the rate and pattern of dispersal of DFG from the STCZ in spring?
M61.	Do nets move at the same rate as the convergence zone?
M62.	Will a combination of fishing activity and effort information with accurate oceanic and nearshore circulation modeling allow accurate predictions of beach and reef debris accumulation?
M63.	What is the best strategy to survey DFG in the North Pacific?
M64.	What percent of the ocean floor is impacted by marine debris?
M65.	How much floating debris ends up on the seafloor?
M66.	Is there a yo-yo effect of debris changing buoyancy from getting fouled then having the fouling mechanisms die off and decompose at depth? If so, how does it work?
M67.	How many fishing nets are made and sold?
M68.	What size derelict fishing gear do we need to look for?

M69.	What are the signatures of derelict fishing gear that can be detected?
M70.	How do we prioritize removal efforts based on economic/ecological impacts?
Oceanography	
O01.	What is the effect of large-scale oceanic regimes (Niño/Niña) on the convergence zone and debris distribution?
O02.	How can we survey large ocean areas and direct removal efforts to large probability areas?
O03.	How will climate change affect North Pacific ocean circulation and thus marine debris movement and accumulation?
O04.	How does external input (e.g., air and water pollution, CO_2 loading) affect the North Pacific system (e.g., circulation, ocean-atmosphere interaction)?
O05.	What are the effects of ENSO and PDO (changes in SST, sea level pressure, wind patterns) in the composition and movement of the frontal zone and subsequent effects of the movement and accumulation of marine debris?
O06.	What is the timing, duration, and mesoscale aspects of the composition of the frontal zone?
O07.	How will the expansion of oligotrophic areas in the North Pacific affect marine debris deposition in the Hawaiian Islands, specifically the NWHI?
O08.	Can convergence information be integrated in time to determine potential MD accumulation?
O09.	What is the relationship among the salinity front, the SST fronts, and the Transition Zone Chlorophyll Front?
O10.	What is the role of local fronts and convergences and how do they compare with the effects of stirring and mixing by ocean gyres flow and eddies?
O11.	How well do satellite derived products detect the actual manifolds in the flow?
O12.	How do wind and surface currents affect the trapping nature of unstable manifolds? Is the "stickiness" decreased?
O13.	What are the effects of ocean acidification on productivity and community composition? (possible effects to primary and secondary productivity and thus detection of convergence zone by chlorophyll concentration?)
O14.	What is the relationship between the location of debris sightings and underlying Lagrangian features of the ocean currents?
Technology	
T01.	How can we further refine the search area given by DELI maps?
T02.	What close-range survey method can effectively locate debris in a variety of sea states/ met conditions?
T03.	What is the best platform (vessel) for at-sea removal of large net aggregates in different weather conditions?
T04.	What is the most efficient/cost-effective configuration of ship, aircraft, UAS, & satellite remote sensing to locate and recover derelict nets on an operational basis?
T05.	What UAS capabilities should be the ultimate goal for the GhostNet Project?
T06.	How well does the DELI pinpoint oceanic convergence? How accurate is the DELI?
T07.	Is there a SAR signature that provides new information on location of oceanic convergence?
T08.	Is there correspondence between the SAR signatures and SST or color fronts?
T09.	Can oceanic convergence be measured at high resolution remotely using time-integrated scatterometer and altimeter wind drift and geostrophic current information?

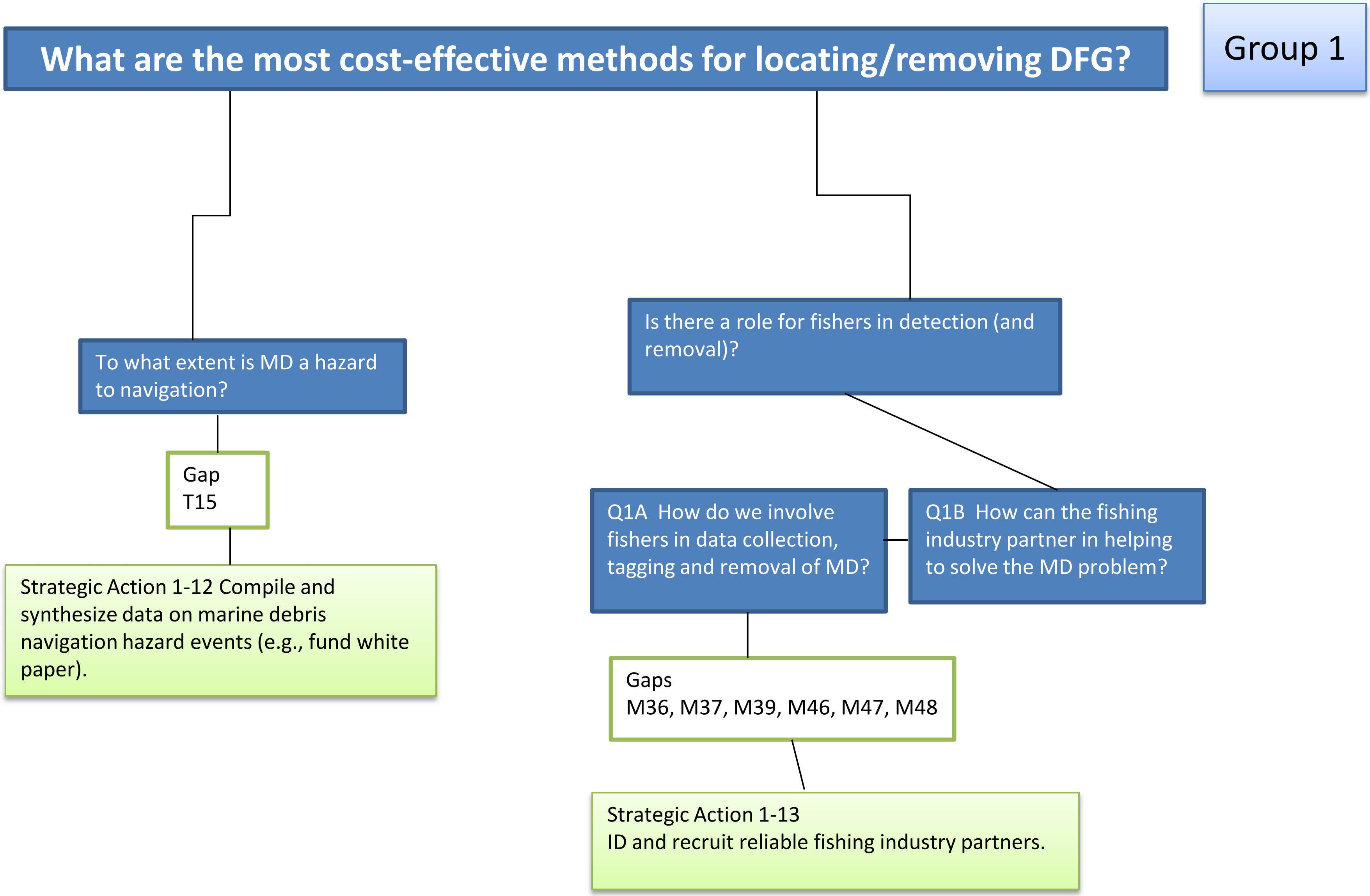
T10.	What combination of instruments has the capability for digital recording and unassisted classification of debris sightings?
T11.	Can satellite remote sensing be used to identify individual MD targets? Or is convergence tracking the most we can expect?
T12.	Can the new GeoEYE-1.5 be used to identify individual nets?
T13.	What is the potential use of both optical and microwave sensors for the direct and indirect detection of marine debris?
T14.	Can we use hyperspectral/multispectral sensors to map MDs based on water states associated with MDs?
T15.	What equipment can be used to announce the presence of DFG and minimize threat to navigation?
T16.	What Coast Guard technology and equipment can be used for at-sea detection efforts?
T17.	Can the source of marine debris be obtained through seeding models with information (e.g., from GhostNet 2005 survey)?
T18.	Does technology presently exist or is available to the civilian sector, for direct detection of marine debris at sea over areas sufficiently large to provide a statistical basis for a debris census that covers the N. Pacific?
T19.	How do we detect floating nets using remote sensors (e.g., microwave, radars, in shorter wavelengths)?
T20.	How do we directly detect plastics (e.g., floats) using sensors (would rely on subpixel analysis of hyperspectral imagery to reveal chemical bonds in the plastic)?
T21.	How do we indirectly detect the interfaces between parcels of water that may trap debris (e.g., using a scatterometer for wind lines and current-related features)?
T22.	What is the effectiveness and feasibility of the use of sensors not currently utilized, to detect marine debris (e.g., SAR imagery or hyperspectral imagery)?
T23.	What, if any, new sensors would be available and effective for fieldwork?
T24.	Would indirect detection techniques be reliable across a variety of sea states and water conditions?
T25.	Can DELI maps provide a quantitative estimate of debris density (sightings per sq km)?
T26.	Can we develop protocols to use shipboard observers to estimate debris densities in various weather/ sea conditions?
T27.	Can we detect the density and size of DFG "patches"?
T28.	What is the most effective platform to carry sensors?

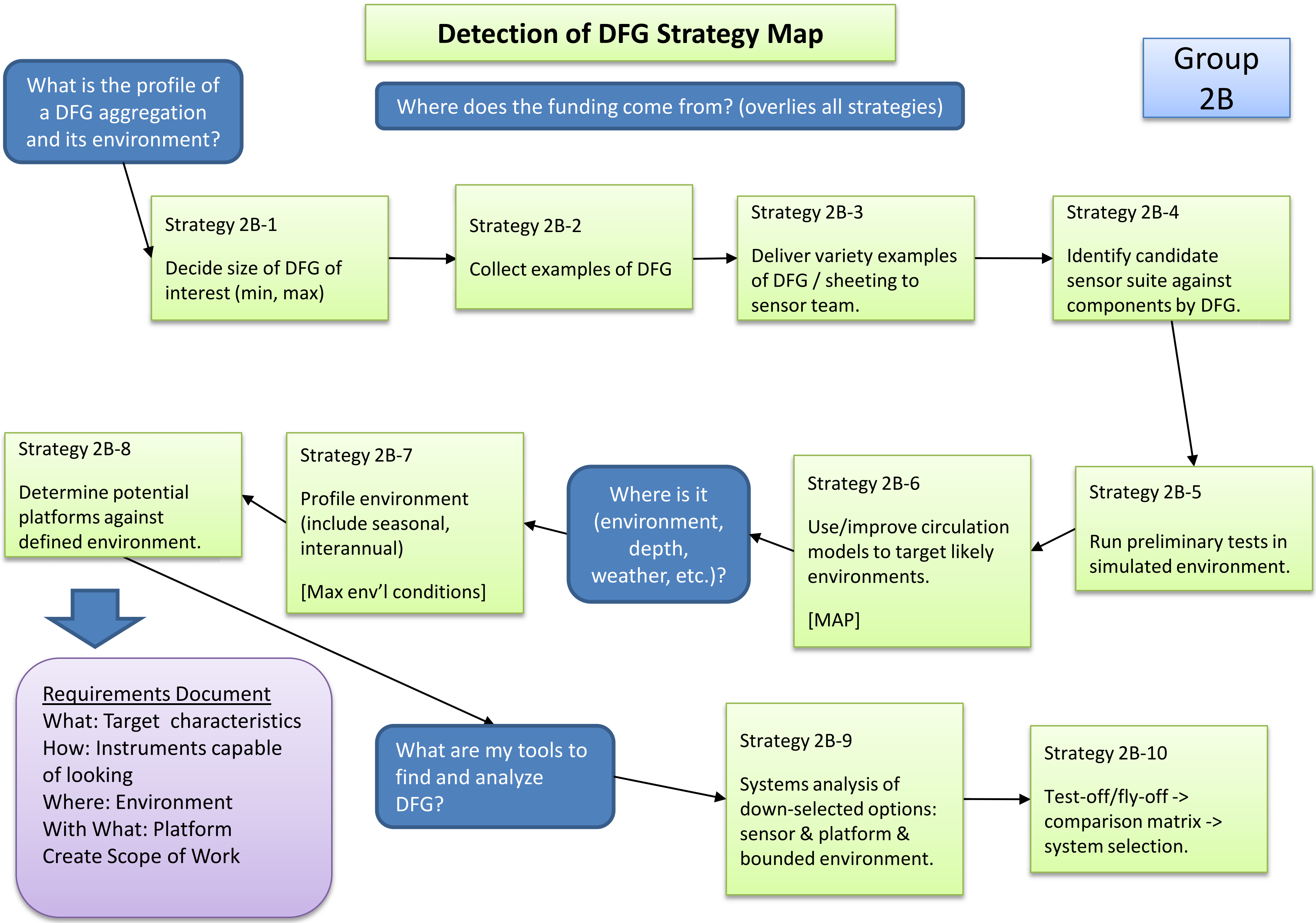
APPENDIX VII. Storyboards


How does DFG move with/within the zones (e.g., STCZ)?
Group 1
Q1B How important are zones and how do we measure them?
Q1A What is the degree of predictability of debris distribution at oceanic fronts in the North Pacific?
Gaps
M25, M44
O14, O03
T26
Strategic Action 1-5
Compile and combine information and data that exists or has been collected on oceanic movement, etc.
Q1B How should we survey and map; how good are the maps?
Gaps
O05, O06, O12
T06
Strategic Action 1-7
Build a comprehensive circulation model (to the 5-10 km area).
Q1B What is the total abundance of MD in the N. Pacific and how does it change over time?
Q1A What is the large scale life cycle of debris sources and sinks?
Gaps
M17, M27, M31, M32, M50, M54, M55, M60
Q1B What is the behavior (movements) and fate of MD after it enters the ocean?
Q1A Is tagging effective?
Gaps
none
Strategic Action 1-3
Test how various types of tags affects movement of nets.
Strategic Action 1-4
Test various types of tags for their effectiveness and tag loss.



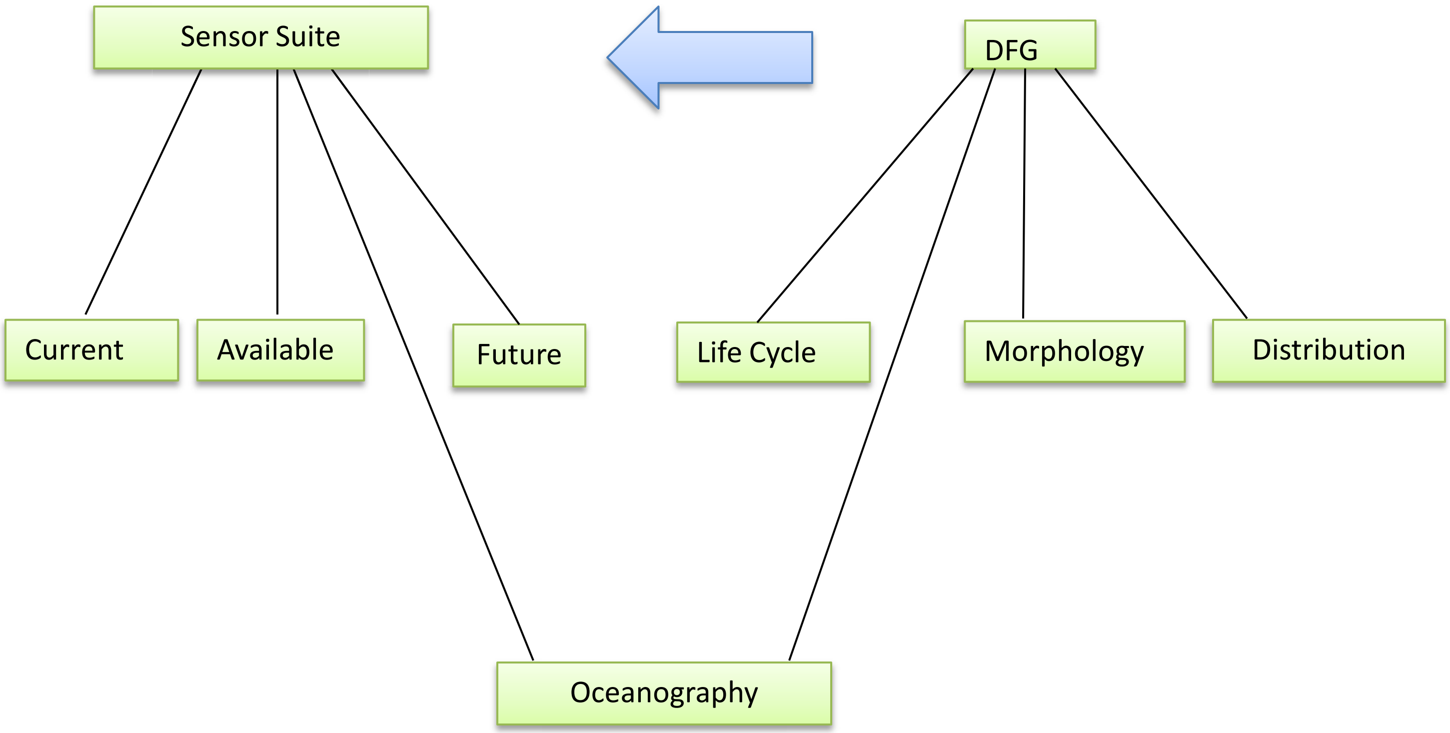
What are the most cost-effective methods for locating/removing DFG?
Group 1
Q1B How well do the sensors we have identified work?
Q1A What are the optimal sensors for direct and indirect detection of MD?
Gaps
T04, T11
Strategic Action 1-8
Look at the effectiveness of the UAS (e.g. with manned aircraft).
Q1B What sensors do we want?
Q1A What is the best technology for low cost debris collection from large areas (e.g. autonomous platforms in STCZ).
Gaps
T12, T13, T16, T22
Strategic Action 1-2
Figure out a way to have a permanent sensor and platform (test bed) for detecting DFG at sea.
Q1B What are the economic considerations of marine debris mitigation (emphasis on detection and removal)?
Q1A How do economic impacts and liability concerns lead to political interest and public awareness of MD?
Q1A What are the economics of MD impacts and recovery strategies?
Gaps
M05, M12, M23, M33, M34, M57
Strategic Action 1-9
Create a business plan for marine debris removal with a defensible budget.
Strategic Action 1-10
Identify funding agencies and collaborative avenues for marine debris mitigation.
Strategic Action 1-11
Quantify costs associated with marine debris impacts (market and non-market).


Group 1
What are the most cost-effective methods for locating/removing DFG?
To what extent is MD a hazard to navigation?
Gap
T15
Strategic Action 1-12 Compile and synthesize data on marine debris navigation hazard events (e.g., fund white paper).
Is there a role for fishers in detection (and removal)?
Q1A How do we involve fishers in data collection, tagging and removal of MD?
Q1B How can the fishing industry partner in helping to solve the MD problem?
Gaps
M36, M37, M39, M46, M47, M48
Strategic Action 1-13
ID and recruit reliable fishing industry partners.


Detection of DFG Strategy Map
Group 2B
What is the profile of a DFG aggregation and its environment?
Where does the funding come from? (overlies all strategies)
Strategy 2B-1
Decide size of DFG of interest (min, max)
Strategy 2B-2
Collect examples of DFG
Strategy 2B-3
Deliver variety examples of DFG / sheeting to sensor team.
Strategy 2B-4
Identify candidate sensor suite against components by DFG.
Strategy 2B-5
Run preliminary tests in simulated environment.
Strategy 2B-6
Use/improve circulation models to target likely environments.
[MAP]
Where is it (environment, depth, weather, etc.)?
Strategy 2B-7
Profile environment (include seasonal, interannual)
[Max env'l conditions]
Strategy 2B-8
Determine potential platforms against defined environment.
Requirements Document
What: Target characteristics
How: Instruments capable of looking
Where: Environment
With What: Platform
Create Scope of Work
What are my tools to find and analyze DFG?
Strategy 2B-9
Systems analysis of down-selected options: sensor & platform & bounded environment.
Strategy 2B-10
Test-off/fly-off -> comparison matrix -> system selection.

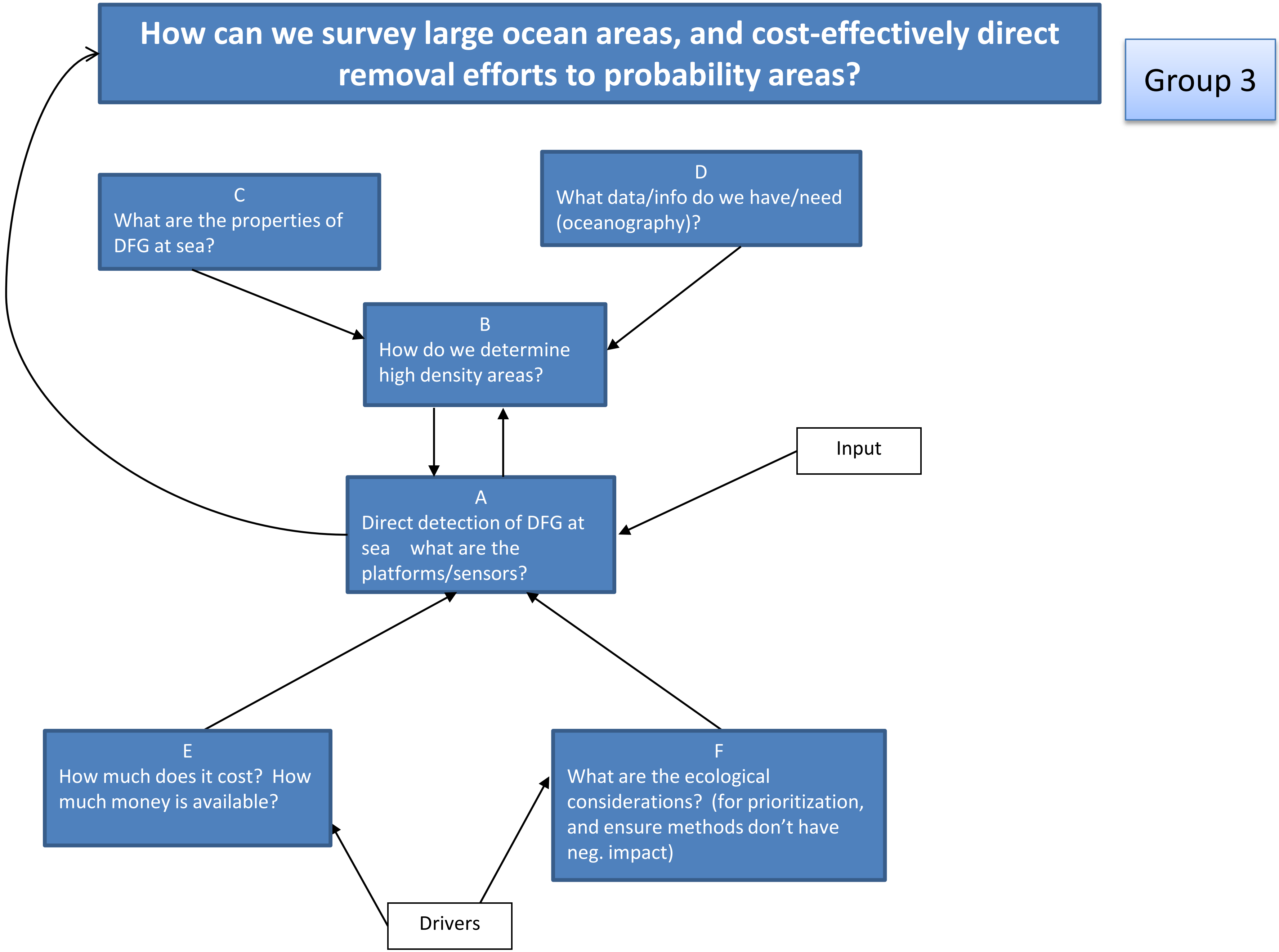
What is the most viable way to detect and track DFG?

Group
2A



Group 2A

Topic	Question	Gaps addressed
Sensors	How do we determine which sensors are adequate to detect DFG and worth pursuing?	M44 T02, T07, T09, T10, T11, T12, T13, T14, T15, T16, T19, T21, T22, T23
Incentives	What incentives can we use and how do we leverage these incentives?	M35, M36, M37, M46, M47, M48, M58
Oceanography	What convergence scales are most important for open ocean accumulation of debris and how will this be affected by climate change?	O01, O03, O04, O05, O06, O07, O08, O09, O12, O13
Temporal Change	What is the life cycle of DFG?	M03, M04, M09, M18, M21, M30, M31, M32, M49, M52, M56, M60, M61
Distribution	What are the large & meso scale accumulation zones for DFG in the North Pacific?	M16, M17, M27, M29, M42, M51, M53 O14
Economic	What have the economic impacts of DFG been in the NW Pacific Islands?	M03, M05, M12, M33, M34, M38, M40 T03, T04, T26
Detection	What kind of detection capabilities currently exist and how can we use current and future sensor technology to aid in detection?	M08, M19, M28, M45, M54, M55, M63 O02, O10, O11 T01, T05, T06, T08, T18, T20, T24, T25
Morphology	What is the most common characteristics and composition of DFG worthy of retrieval?	M10, M11, M24, M25, M26, M50
Ecological	What are the positive and negative ecological impacts of DFG?	M01, M02, M13, M14, M15, M20, M39, M57
Modeling	Can modeling be used to characterize mass distribution and movement of DFG?	M07, M23, M41, M43, M59, M62 T17


How can we survey large ocean areas, and cost-effectively direct removal efforts to probability areas?
Group 3
C
What are the properties of DFG at sea?
D
What data/info do we have/need (oceanography)?
B
How do we determine high density areas?
Input
A
Direct detection of DFG at sea what are the platforms/sensors?
E
How much does it cost? How much money is available?
F
What are the ecological considerations? (for prioritization, and ensure methods don't have neg. impact)
Drivers

Group 3

A - How do we detect DFG? How well do we detect DFG?

Gaps
T02, T10, T11, T12, T16, T18, T19, T99
New Gap #1 – What is the most effective platform to carry sensors?

Strategy 3-A1
Develop or find effective sensor(s) to use in detecting DFG at sea.

Strategy 3-A2
Test delectability of DFG with multiple sensors.

Strategy 3-A3
Develop or find effective platform(s) to use in detecting DFG at sea.

B – What tools / info can we apply to locating DFG?

Gaps
M59, M62, O08, T01, T06, T07, T08, T09, T17, T21, T24, T25

Strategy 3-B1
Determine the relationship b/w oceanographic features and DFG. (population, density, distribution)

Strategy 3-B2
Conduct surveys to determine population density distribution of DFG.

Group 3

C – What are the properties of DFG (at sea). How much DFG? And fate?

Gaps
M04, M08, M09, M11, M21, M26, M27, M28, M32, M42, M50, M52, M56

Strategy 3-C1 Understand life-cycle of DFG.

D – What are all the pieces needed to model DFG, and are data available to fill

Gaps
M06, M07, M30, M41, M43, M49

Strategy 3-D1 Determine the leeway of DFG.

E – What does it all cost?

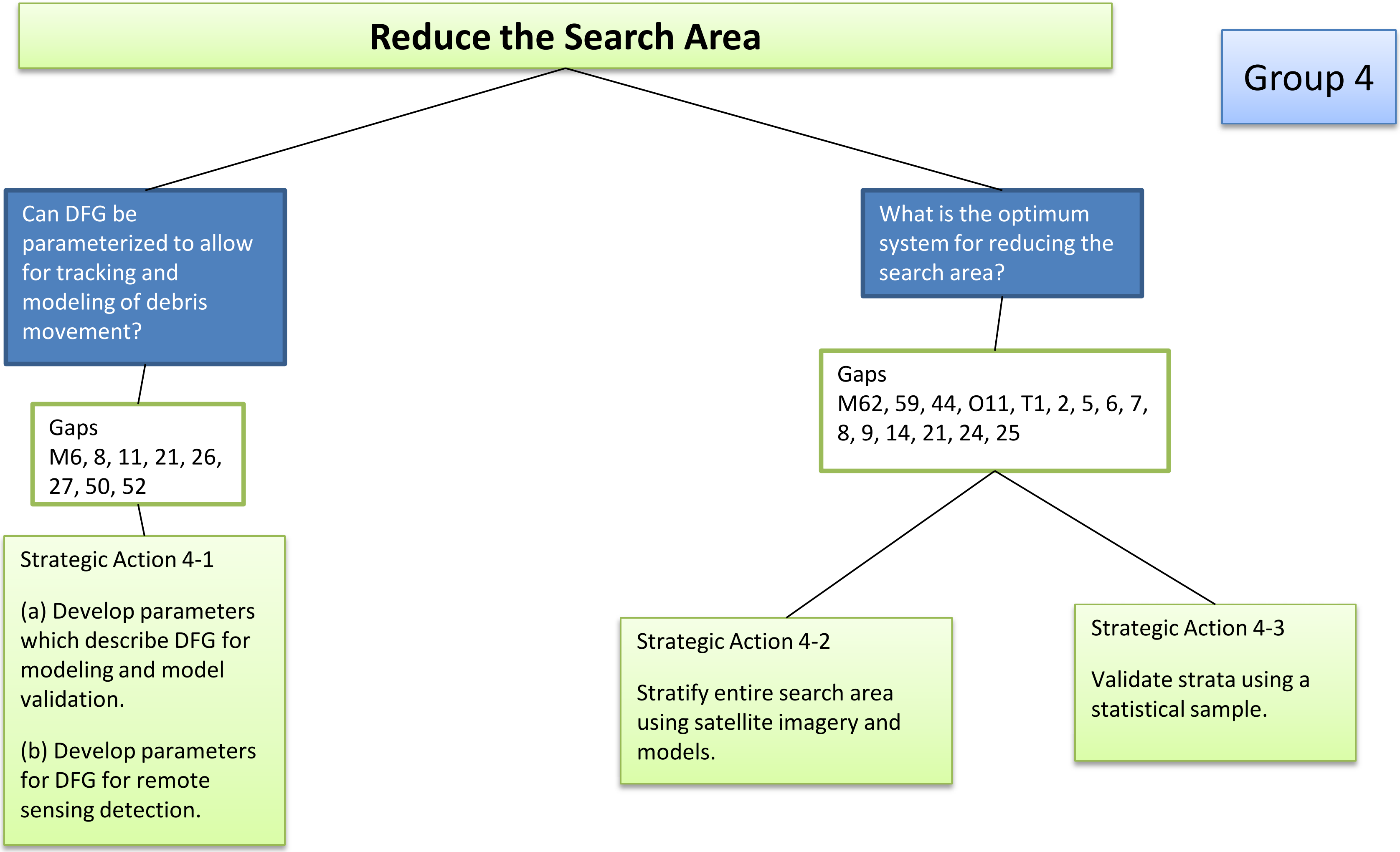
Gaps
M03, M05, M12, M34, M37, M38, M58
T04

Strategy – none provided.

F – What are the impacts of DFG?

Gaps
M01, M02, M14, M15, M23, M33, M39, M57
New Gap #2 – How do we prioritize removal efforts based on economic/ecological impacts?

Strategy. Explore on-site pre-contact removal plan.


Reduce the Search Area
Group 4
Can DFG be parameterized to allow for tracking and modeling of debris movement?
Gaps
M6, 8, 11, 21, 26, 27, 50, 52
Strategic Action 4-1
(a) Develop parameters which describe DFG for modeling and model validation.
(b) Develop parameters for DFG for remote sensing detection.
What is the optimum system for reducing the search area?
Gaps
M62, 59, 44, O11, T1, 2, 5, 6, 7, 8, 9, 14, 21, 24, 25
Strategic Action 4-2
Stratify entire search area using satellite imagery and models.
Strategic Action 4-3
Validate strata using a statistical sample.

Group 4

What is the cost of doing nothing?

Strategy 4-4

Is it worth it to develop research/monitoring plan and associated costs?

Gaps
M03, 25, 38, 46, 52, 54

Strategy 4-5

Develop and validate a mass balance for DFG:

- Identify sources
- Identify sinks
- Standing stock
- Partition pathways

Gaps
M01, 02, 13, 14, 33, 39, 55, 57

Strategy 4-6

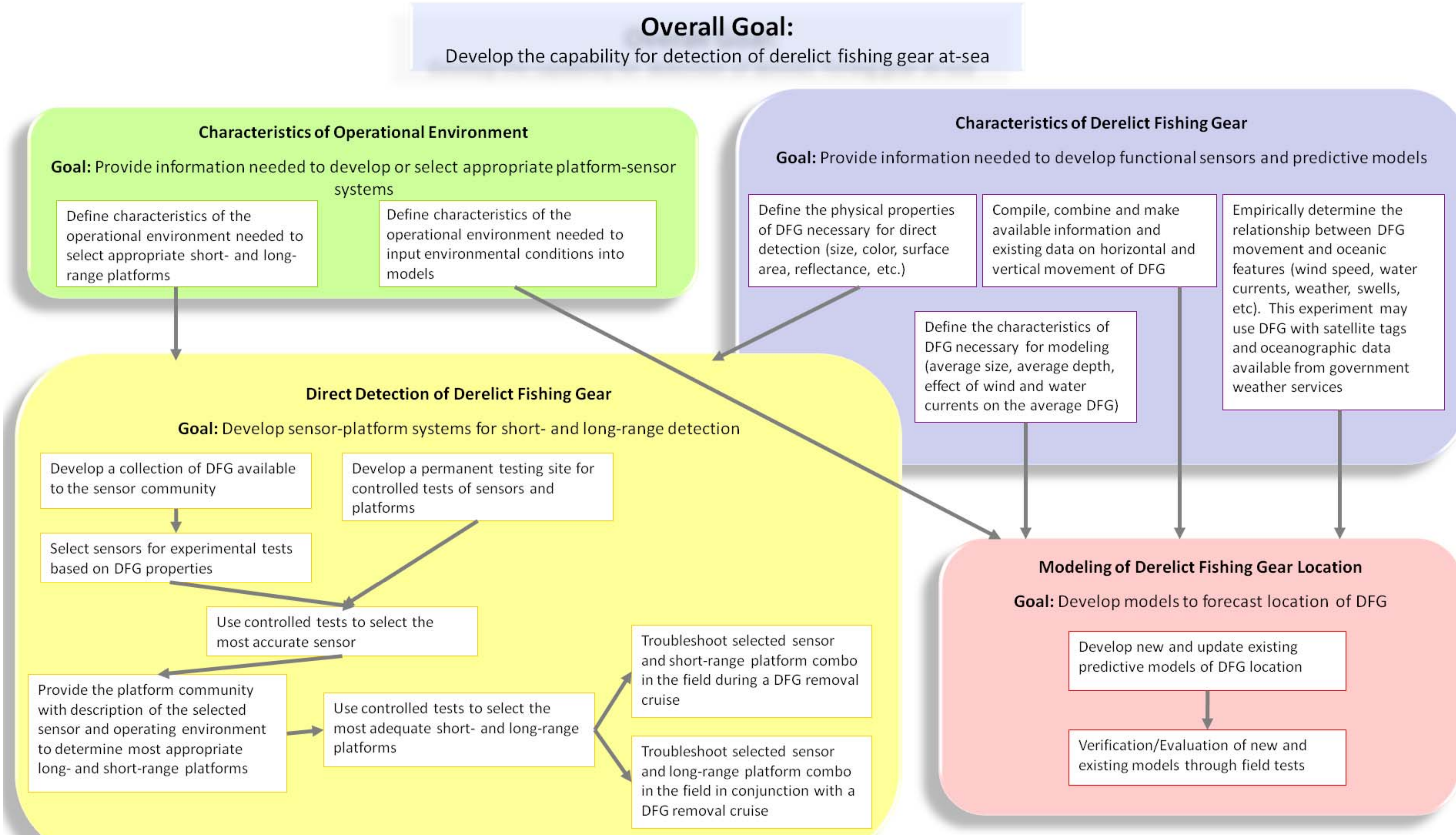
Estimate costs of impacts.

What, if any, sensors are available and effective for fieldwork? (and platforms)

Gaps
T13, 16, 19, 20, 26, 10, 18, 22
New gap = Is there a unique spectral signature for MDs?

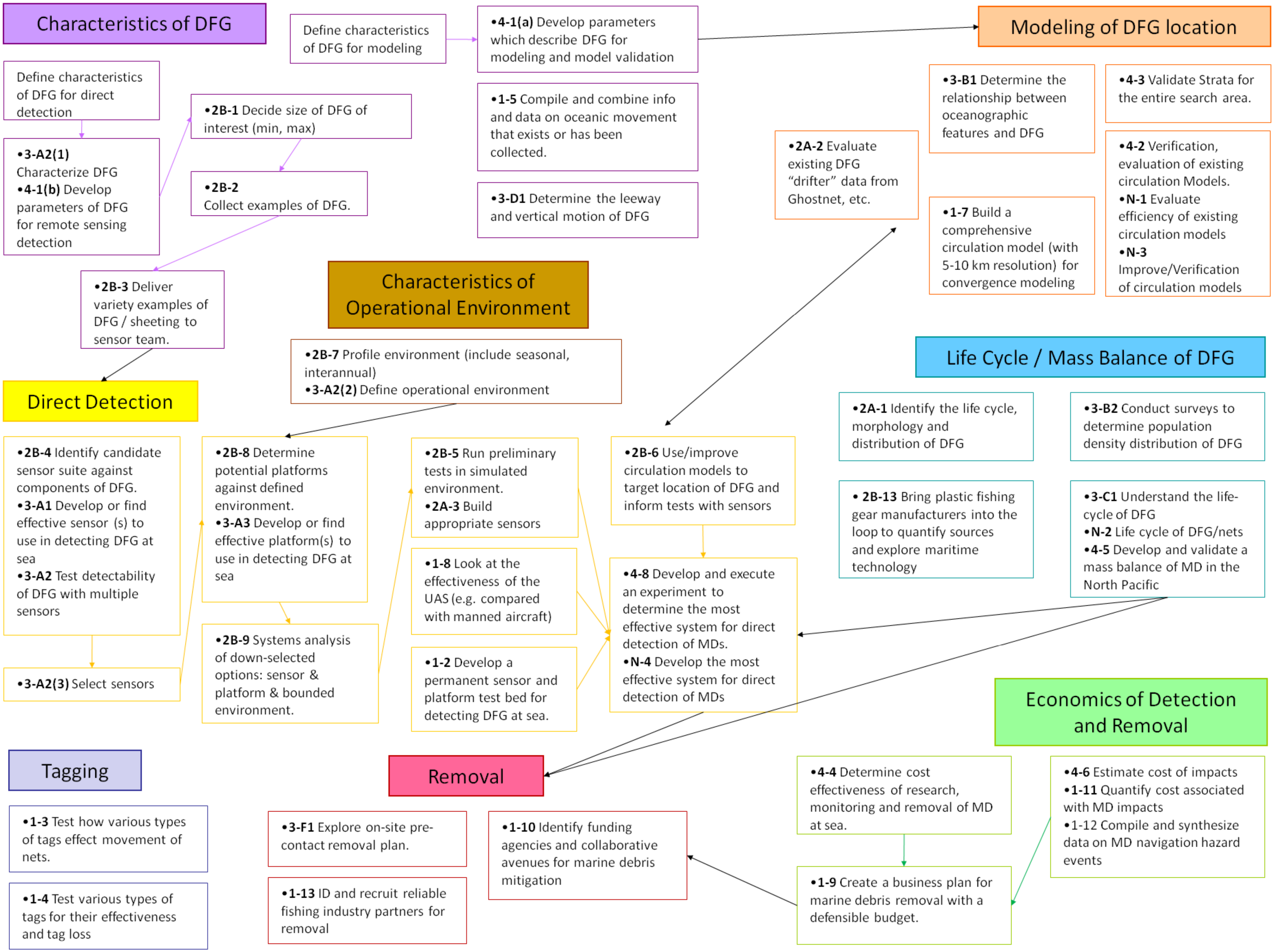
Strategy 4-8

Develop and execute an experiment to determine the most effective system for direct detection of MDs.


Overall Goal:
Develop the capability for detection of derelict fishing gear at-sea
Characteristics of Operational Environment
Goal: Provide information needed to develop or select appropriate platform-sensor systems
Define characteristics of the operational environment needed to select appropriate short- and long-range platforms
Define characteristics of the operational environment needed to input environmental conditions into models
Characteristics of Derelict Fishing Gear
Goal: Provide information needed to develop functional sensors and predictive models
Define the physical properties of DFG necessary for direct detection (size, color, surface area, reflectance, etc.)
Compile, combine and make available information and existing data on horizontal and vertical movement of DFG
Empirically determine the relationship between DFG movement and oceanic features (wind speed, water currents, weather, swells, etc). This experiment may use DFG with satellite tags and oceanographic data available from government weather services
Define the characteristics of DFG necessary for modeling (average size, average depth, effect of wind and water currents on the average DFG)
Direct Detection of Derelict Fishing Gear
Goal: Develop sensor-platform systems for short- and long-range detection
Develop a collection of DFG available to the sensor community
Develop a permanent testing site for controlled tests of sensors and platforms
Select sensors for experimental tests based on DFG properties
Use controlled tests to select the most accurate sensor
Provide the platform community with description of the selected sensor and operating environment to determine most appropriate long- and short-range platforms
Use controlled tests to select the most adequate short- and long-range platforms
Troubleshoot selected sensor and short-range platform combo in the field during a DFG removal cruise
Troubleshoot selected sensor and long-range platform combo in the field in conjunction with a DFG removal cruise
Modeling of Derelict Fishing Gear Location
Goal: Develop models to forecast location of DFG
Develop new and update existing predictive models of DFG location
Verification/Evaluation of new and existing models through field tests

APPENDIX VIII. Strategic Action Outline

Actions from the different groups are here presented in thematic areas, with some indication of order within and connectivity among areas. Individual actions are outlined in greater detail in Appendix IX.


Characteristics of DFG
Define characteristics of DFG for modeling
•4-1(a) Develop parameters which describe DFG for modeling and model validation
Modeling of DFG location
Define characteristics of DFG for direct detection
•2B-1 Decide size of DFG of interest (min, max)
•1-5 Compile and combine info and data on oceanic movement that exists or has been collected.
•3-B1 Determine the relationship between oceanographic features and DFG
•4-3 Validate Strata for the entire search area.
•3-A2(1) Characterize DFG
•4-1(b) Develop parameters of DFG for remote sensing detection
•2B-2 Collect examples of DFG.
•2A-2 Evaluate existing DFG "drifter" data from Ghostnet, etc.
•4-2 Verification, evaluation of existing circulation Models.
•N-1 Evaluate efficiency of existing circulation models
•N-3 Improve/Verification of circulation models
•3-D1 Determine the leeway and vertical motion of DFG
•1-7 Build a comprehensive circulation model (with 5-10 km resolution) for convergence modeling
•2B-3 Deliver variety examples of DFG / sheeting to sensor team.
Characteristics of Operational Environment
•2B-7 Profile environment (include seasonal, interannual)
•3-A2(2) Define operational environment
Life Cycle / Mass Balance of DFG
Direct Detection
•2A-1 Identify the life cycle, morphology and distribution of DFG
•3-B2 Conduct surveys to determine population density distribution of DFG
•2B-4 Identify candidate sensor suite against components of DFG.
•3-A1 Develop or find effective sensor (s) to use in detecting DFG at sea
•3-A2 Test detectability of DFG with multiple sensors
•2B-8 Determine potential platforms against defined environment.
•3-A3 Develop or find effective platform(s) to use in detecting DFG at sea
•2B-5 Run preliminary tests in simulated environment.
•2A-3 Build appropriate sensors
•2B-6 Use/improve circulation models to target location of DFG and inform tests with sensors
• 2B-13 Bring plastic fishing gear manufacturers into the loop to quantify sources and explore maritime technology
•3-C1 Understand the life-cycle of DFG
•N-2 Life cycle of DFG/nets
•4-5 Develop and validate a mass balance of MD in the North Pacific
•1-8 Look at the effectiveness of the UAS (e.g. compared with manned aircraft)
•4-8 Develop and execute an experiment to determine the most effective system for direct detection of MDs.
•N-4 Develop the most effective system for direct detection of MDs
•2B-9 Systems analysis of down-selected options: sensor & platform & bounded environment.
•3-A2(3) Select sensors
•1-2 Develop a permanent sensor and platform test bed for detecting DFG at sea.
Economics of Detection and Removal
Tagging
Removal
•4-4 Determine cost effectiveness of research, monitoring and removal of MD at sea.
•4-6 Estimate cost of impacts
•1-11 Quantify cost associated with MD impacts
•1-12 Compile and synthesize data on MD navigation hazard events
•1-3 Test how various types of tags effect movement of nets.
•3-F1 Explore on-site pre-contact removal plan.
•1-10 Identify funding agencies and collaborative avenues for marine debris mitigation
•1-13 ID and recruit reliable fishing industry partners for removal
•1-9 Create a business plan for marine debris removal with a defensible budget.
•1-4 Test various types of tags for their effectiveness and tag loss

APPENDIX IX. Strategic Action Templates

Actions are numbered by group (1, 2A, 2B, 3, 4) or “N,” referring to a group of actions developed within the subject-matter groups. Specific actions (except for those beginning in “N”) can be found on that group’s storyboard. Note that many fields are not completed; these templates are included to capture the group’s work, not to indicate that planning is complete or offer these strategic actions as ready to implement as they are.

Action #	Subject Matter Gp	Action Needed	Gaps	Steps	Organizations to involve	Who has technology	Impediments	Other non-MD benefits
1-2	T	Develop a permanent sensor and platform test bed for detecting DFG at Sea.	T12, T13, T16, T22					
1-3	M	Test how various types of tags affect movement of nets		Implement a tagging program with Federal agencies and NGOs , Test both vertical and horizontal movement in water, Develop recording methods that better classify DFG	NOAA, USCG, local fishing vessels, universities	Tag manufacturers, NOAA, USCG, fishing industry coops	Lost tags, different nets will act differently	Other uses for tags after testing
1-4	T	Test various types of tags for their effectiveness and tag loss						
1-5	T	Compile and combine info and data on oceanic movement that exists or has been collected	M25, O14, O03, M44, T26					
1-7	O	Build a comprehensive circulation model (with 5-10 km resolution) for convergence modeling	T01, O12, O06, O05		Navy, CG, JPL, IPRC Post Docs, Dave Foley, Ocean Water (Jeff Polovina)		Verifying Data, Difficulty of working at sea, Question of Scale, Understand Characteristics of debris	Model validation, Climate Change
1-8	T	Look at the effectiveness of the UAS (e.g. compared with manned aircraft)	T04, T11					
1-9	M	Create a business plan for marine debris removal with a defensible budget	M05, M12	Use action 1-11 as foundation for cost benefit analysis; See action 4-4 "is it worth it?"				
1-10	M	Identify funding agencies and collaborative avenues for marine debris mitigation		ID funding resources/agencies including NOAA MDP: Federal, NGO, State, Private patrons; Explore "match-making" technology to increase (e.g. chat rooms?) collaborative work; Create web page repository of funding opportunities; Conduct forums to build networking and grant opportunities	NOAA	NOAA	Important but not crisis issues, so attention is diverted	
1-11	M	Quantify cost associated with MD impacts	M24, M33, M34, M57	Identify impacts (Dovetail with 4-4): economic, ecological, safety; Lit search on the area listed above for known information. Identify needs, and for each determine plan. This could include studies to put $ on entanglement/habitat loss, ship hazards, beach cleanups, tourism, etc.	Fishing community, researchers (protected species and coral reef)	City, State tourism agencies, USCG	Hard to assign monetary value to loss of life, and loss of habitat	Monetary value for reef could transfer to ship grounding events (estimate damage costs)
1-12	M	Compile and synthesize data on MD navigation hazard events	T15	ID what data exist and obtain data, ID lead organization/individual to analyze data (e.g., contract or fed on staff), Publish document in appropriate journal (e.g., Environmental Research), *Thorough lit. search to include conf. proc., e.g., Environmental Research 108, 2008, pp. 131-139. (new Moore publication)	USCG, NOAA, BoatUS	Same	funding; Incomplete data sets; unreported events	Safer environment
1-13		ID and recruit reliable fishing industry partners	M36, M37, M39, M46, M47, M48	ID Fisheries impacted by MD; ID Fishing org/agencies to engage	Mike Stone (Fury Group) Brett Payne (United Catcher boat, other local fishers)	Individuals with personal relationships of integrity with individual fishers	Reliable engagement, consistency of motives among fishers and mitigation leaders	
2A-1		Identify the life cycle, morphology and distribution of DFG	M03, M04, M09, M18, M21, M30, M31, M32, M49, M52, M56, M60, M61; M16, M17, M27, M29, M42, M51, M53, O14; M10, M11, M24, M25, M26, M50	Work to quantify the movement of DFG in the open ocean, Identify sources and sinks of marine debris, Back calculate amount of DFG necessary to have amount deposited on reef (census). Mass balance, Lab experiments to understand degradation, agglomeration rates, effects of wind/ DFG	CRED/NOAA, industry (fishers)	CRED/NOAA	We don't have information on what's collecting out there. We need industry to provide some measure of source.	
2A-2		Evaluate existing DFG "drifter" data from ghostnet, etc	This action will help us to understand the movement of MD from previously tagged DFG; O01, O03, O04, O05, O06, O07, O08, O09, O12, O13; M07, M23, M41, M43, M59, M62, T17	Compile available data, Integrate with oceanographic data	ATI, NOAA, NASA, Navy, IPRC	NOAA, IPRC, ATI, CG	Lack of drifter data, size/ scale of circulation models	Search and rescue, circulation patterns
2A-3		Build appropriate sensors	What sensors are appropriate? M44; T02, T07, T09, T10, T11, T12, T13, T14, T15, T16, T19, T21, T22, T23; M08, M19, M28, M45, M54, M55, M63, O02, O10, O11, T01, T05, T06, T08, T18, T20, T24, T25	Evaluate existing data from sensors, Perform controlled tests of potential sensors, Field test promising sensors, Open development structure for upcoming sensor advancements	ATI, NOAA, NASA, USCG	ATI, NOAA, NASA	Knowledge of region→provide oceanographic information to give idea of what's an appropriate sensor, Knowledge of DFG lifecycle/composition	Potential image analysis of other objects in the entire open ocean
2B-1		Decide size of DFG of interest (min, max)		Prioritizing problem; water column or afloat masses? Determining what size is "detectable"? by remote sensing	NOAA, USFWS, Engineers?, CG, TNC, UH, Non-profits, AMRF	NASA, Lockheed Martin, NOAA CoastWatch, JPL	Funding, Agreeing on minimum detectable size?	Safety, Hazard to Navigation doesn't really fit

Action #	Subject Matter Gp	Action Needed	Gaps	Steps	Organizations to involve	Who has technology	Impediments	Other non-MD benefits
2B-2		Collect examples/samples of DFG		Identify how much, where, etc., Who does it?, How it's done?, Who pays?, Timeframe?, Equipment, Resources, Where destined	Volunteers, Stakeholders, Contractors, CG, Recyclers	Anyone with a boat! Those who have access to beach debris	Funding, Availability, Seasonal/weather	Historical reference for future use? Recreational benefit, Economical benefit – tourist areas, Data points?
2B-3		Deliver variety of examples of DFG to sensor engineers		Collect, classify, sort, label, package; Deliver	Boater, Driver, Volunteers	Widely available; USPS, DHL, FedEx	Funding, Traffic, Schedule/timeframe, Quantities sufficient?	Economic boost for payees
2B-4		Identify candidate sensor suite against components of DFG	What we are looking for (profile DFG)	1. define size, minimum/maximum elements 2. define sensors that will detect 3. define environment to operate in 4. define candidate platforms; evaluate system level for down selection for testing against 1-4	Sensor engineering Science/materials subject matter experts, NOAA DFG collectors	DOE, NASA remote sensing	Funding at all gates	Perhaps a suite of sensors usable for additional detection (threats) SAR
2B-8		Determine potential platforms against defined operational environment	Platform that has range, power, mass, etc.	Define sea state (max) to operate in, Define range/map, Refine models for prediction (currents, winds, weather)	FAA, NASA, Navy, CG, Industry	Industry	FAA, large support team	
2B-9		System analysis of down-selection options	Testing to validate options	Test against sensor, platform and bounded environment	NASA/Industry-sensor, SCI, End-user?	NOAA, Industry	Scope, funding	Better understanding of sensor capabilities/limitations; platform
2B 13		Bring plastic fishery gear manufacturers into the loop to get quantity data and explore maritime technology	We don't know who or where they are or how many, Contact information, Industry Associations	Identify Manufacturers – Quantify Sales; Identify Outlets – Sales Data; Identify Users – Purchase Data and Replacement Data	ACC, Foreign Economic Liaisons, World Trade Organizations, Fishery Vessel Masters and Agents, UNEP	State Department - Business Associations, Trade Association	Cost Funding – Reluctance to report data; International cooperation – Distance; Foreign Language	Economic Information - Education
3-A1		Develop or find effective sensor(s) to use in detecting DFG at sea	T10, T11, T12, T19					
3-A2 (1 of 3)		Characterize DFG		1. Obtain DFG (representation of targets at-sea) 2. Test dielectric properties, spectra 3. Define morphology, components 4. Pull characteristics information from data search (see Technology Data Mining Action)	Navy (ONR), GhostNet, Coast Guard, sensor manufacturers			
3-A2 (2 of 3)		Define operational environment		1. Identify geography/range (whole ocean vs. gyre), 2. Identify weather conditions, 3. Identify seasons/days, 4. Identify sea state (max)				
3-A2 (3 of 3)		Select sensors		1. Assemble list of sensors, 2.Let out RFP with: a) specs of DFG, b. characteristics of debris field (density, sizes of DFG - 1M□on surface and larger); 3. Vendors will run tests with their sensors, 4. Test in operational setting with constraints				
3-A2 (with 3 sub-actions)		Test detectability of DFG with multiple sensors	T18	1. Obtain DFG, 2. Characterize DFG: dielectric properties, spectra, morphology, components 3. Assemble list of existing sensors/vendors 4. Define operational environmental constraints; geography, weather, sensor, size of area, sea state 5. Evaluate platforms that will work with sensors in environment	Sensor manufacturers, labs			
3-A3		Develop or find effective platform(s) to use in detecting DFG at sea	T2, T16, T18, T28					
3-B1	O	Determine the relationship between oceanographic features and DFG	M59, M62, O08, T01, T06, T07, T08, T09, T17, T21, T24, T25	Verification with drifting DFG	Navy, JPL, CG, NOAA			
3-B2		Conduct surveys to determine population density distribution of DFG		Determine Sensors, platforms, survey design, and statistical analyses	NOAA, USCG, Sensor Experts, Platform Experts (folks at this workshop)	Same	Sample size required is unknown, Inter-annual variation, Challenging operating area, Funding	

Action #	Subject Matter Gp	Action Needed	Gaps	Steps	Organizations to involve	Who has technology	Impediments	Other non-MD benefits
3-C1		Understand the life-cycle of DFG	M04, M08, M09, M11, M21, M26, M27, M28, M32, M42, M50, M52, M56	ID where /how many DFG enter the ocean, Create studies to determine: Age of nets (stretch, fouling), Drift, Degradation, Behavior (movement), Accumulation on reef/beach	NOAA, Tony Andrady (degradation), Fishing community, Oceanography community, University scientists, Algalita	Same	Scale of problem, Unreported loss of Fishing Gear, Parameters that confound age information	
3-D1		Determine the leeway and vertical motion of DFG	Horizontal trajectory prediction of individual DFG; M06, M07, M30, M41, M43, M49	Determine size range and shape of DFG, Pick typical DFGs, Test/observe vertical motion, Determine causes of vertical motion, Determine if vertical motion affects horizontal motion, Determine leeway of typical DFG	Leeway – Art Allen	Leeway - USCG	Leeway field experiments require ship time	
3-F1		Explore on-site pre-contact removal plan	M01, M02, M14, M15, M23, M33, M39, M57, M70	Determine feasibility of daily/weekly surface net surveys/removal at islands/atolls, Find funding/lead organization, Work out field details: # of people needed/how support, What to do with nets	NOAA, local organizations (i.e., for NWHI=Monument), Coast guard-safety, Local recycle/power companies, other support field camps (i.e., seal/FWS Midway)	CRED, Monk Seal field camps, volunteers or fishermen ~ mainland, MD Program - funding	Weather, safety, cost, remote	People at remote locations can observe other environmental events (e.g., bleaching)
4-1		Develop parameters which describe DFG for modeling and model validation	M50, M27, M21	Track horizontal movement, Track vertical movement with TDR; use different sizes of debris, Develop a fouling rate. How does fouling affect density and buoyancy, Develop wind/current effects for different sizes	NOAA, University, USCG	Same	Any variation in size, density, wind, current, type of debris will change movement/model	Add to current models; search/rescue
4-2		Verification/evaluation of existing circulation Models. Purpose is to stratify (characterize) entire search area using satellite and models/theory	O08, M42, T24, O10, T09, etc.	Lifecycle/characteristics, Understand interaction of DFG with currents/winds, waves, Synthesize existing tagged DFG data, Effect of fouling on nets, Scaled down simulation experiments, Synthesis of existing models comparison, Predictive capacity?, Nested highres develop sub-model	Navy, JPL, NOAA, IPRC	IPRC	Verification data	Search rescue, ecosystem process understanding, climate change, methods of model verification
4-3		Validate Strata for the entire search area using a statistical sample	Statistical Validation of strata will allow improved estimate of debris density	Determine minimum size/parameters of targets to detect, Determine acceptable sampling error, Choose survey methodology/technology, Implement survey, Report/analyze results	Oceanographers, modelers		How stable in time/space is the strategy	
4-4	M	Determine cost effectiveness of research, monitoring and removal of MD at sea.	We don't have a clear idea of high, medium and low DFG concentrations and their movement over time. We don't know the cost of doing nothing.	Determine costs of surveys: (a) satellite, (b) aircraft, (c) UAV. Communicate cost in terms of square meters * Determine cost of each survey * Compare to the cost of doing nothing i. Cost of beach cleanups ii. Costs to navigation iii. Cost of ecological impacts	NOAA, CG, Private research orgs, Cities, NASA, Lockheed Martin, States	Same	Lack of comprehensive plan, Lack of cost estimate for plan, Lack of cost estimate of doing nothing,	Healthier ocean and marine life., Usable beaches
4-5		Develop and validate a mass balance of MD in the North Pacific	M03, M25, M38, M46, M52, M54	Identify sources, Identify sinks, Estimate standing stock, Partition pathways	NOAA, NASA, DOD		Funding and lack of knowledge	Ecosystem information
N-1	O	Evaluate efficiency of existing circulation models			Navy, CG, Jet Propulsion Lab (JPL), NOAA (Ocean Watch), IPRC	Nikolai Maximenko (IPRC), Dave Foley	Verification data, Characteristics and behavior movement of DFG, Spatial and temporal scales, Difficulty with getting in field, Lifecycle of DFG, Funding	Search and rescue, Methodology for model verification, Ecosystem dynamics, Product, Migration
N-2	O	Lifecycle of DFG/nets			NOAA CRED, State Department, RFMO, NMFS	RFMOs	Funding, Not enough data on DFG, International cooperation, Illegal fishing (IUU?)	
N-3	O	Improve circulation models/ verification		Understand interaction of DFG with currents and winds, Synthesize existing (and tagged) DFG data, Continue tagging debris, Scale models to ROI, Validate and work on presence	NAVY, CG, JPL, IPRC, NOAA, ATI	Nikolai, Foley, NOAA, IPRC, ATI, CG, Navy	Verification data, Difficult in obtaining field data	Search and Rescue, model verification, Ecosystem damage
N-4	O	Develop the most effective system for direct detection of MD	T23, T10, T13, T16, T18, T19, T20, T22, T26, N1	Develop a spectral library for MD types, Test sensors against known targets from high altitude airborne platforms, Hyperspectral (AVIRIS), Multispectral Thermal (MASTER), Scatterometer (Polscat), Radar (UAVSAR, GLISTIN, other?),	NOAA, NASA, JPL, Dryden, USGS	NASA, Lockheed Martin	Funding	Other UAS applications

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