Buoy Vandalism Experienced by NOAA National Data Buoy Center

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Abstract. Data buoy vandalism, which is an unlawful and willful interference with moored data buoys, has been a troublesome problem for the U.S. National Oceanic and Atmospheric (NOAA)/National Data Buoy Center (NDBC) and other buoy operators around the world. NDBC has three buoy networks - Weather and Ocean Platform (WxOP) program, Tropical Atmosphere/Ocean (TAO) buoy program, and the Tsunameter buoy program. In addition to the significant financial impact to NDBC's buoy programs and operations, vandalism disrupts the vital data collected and reported by moored buoys, which place lives, property, and economies in peril. Vandalism is not unique to just NDBC's buoy systems but is a national and international issue affecting both research and operational systems. This paper presents various vandalism incidents experienced by NDBC's three buoy networks. Prevention of buoy vandalism, including buoy and mooring system modifications, education and outreach, statutory penalty and enforcement, interagency efforts, and international cooperation and efforts, are also discussed.

I. INTRODUCTION

The U.S. National Data Buoy Center (NDBC) is a unit of U.S. National Weather Service's (NWS) Office of Operational Systems (OOS) in the National Oceanic and Atmospheric Administration (NOAA). NDBC has three major real-time ocean observing networks/programs: (1) Weather and Ocean Platform (WxOP) Program (with 116 moored buoys and 53 land-based C-MAN sites collecting meteorological and ocean data), (2) Tropical Atmosphere Ocean (TAO) Program (with 55 surface buoys/moorings and 4 subsurface moorings collecting ocean climatic data), and (3) Tsunameter Program (with 39 buoys/moorings collecting and reporting water column height data to monitor open ocean tsunamis). Figure 1 shows the locations of these platforms. In general, WxOP buoys are located around U.S. coastal waters (i.e., U.S. East coast, West coast, Gulf of Mexico, and Hawaii Islands) and Great Lakes. The TAO buoys are located along the Pacific equatorial region (from 165E to 95W) while the Tsunameter buoys are located predominately in the Pacific Ocean with some in Atlantic Ocean and Gulf of Mexico.

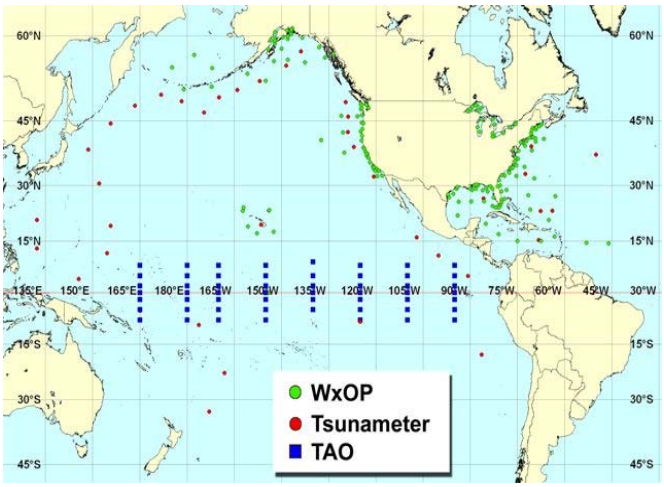

Figure 1 NDBC station location map

These data buoys, which are located in robust biotic ocean and marine areas, may experience damage from natural environmental factors (such as wind, waves, ocean currents, corrosion, fish bite, marine growth, etc.). In addition, they may also be damaged accidentally or from unlawful interference in a deliberate manner. In this paper, any unlawful interference with ocean data buoys (including willful or malicious destruction, defacement, or theft) are regarded as acts of vandalism. In general, buoy vandalism damage may occur by:

- Vessels tying up to the buoys as temporary anchors or safe havens,
- Vessels collision causing buoy equipment and structural damage,
- Fishing vessel net or line entanglement and subsequent cutting of the mooring line to recover their fishing gear or free the vessel from the mooring,
- Fishing operations using the buoys as Fish Aggregating Devices (FADs), and
- Theft of the buoy system or its equipment (e.g., sensors, solar panels, etc.).

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14. ABSTRACT
Data buoy vandalism, which is an unlawful and willful interference with moored data buoys, has been a troublesome problem for the U.S. National Oceanic and Atmospheric (NOAA)/National Data Buoy Center (NDBC) and other buoy operators around the world. NDBC has three buoy networks - Weather and Ocean Platform (WxOP) program, Tropical Atmosphere/Ocean (TAO) buoy program, and the Tsunameter buoy program. In addition to the significant financial impact to NDBCs buoy programs and operations, vandalism disrupts the vital data collected and reported by moored buoys, which place lives, property, and economies in peril. Vandalism is not unique to just NDBCs buoy systems but is a national and international issue affecting both research and operational systems. This paper presents various vandalism incidents experienced by NDBCs three buoy networks. Prevention of buoy vandalism, including buoy and mooring system modifications, education and outreach, statutory penalty and enforcement, interagency efforts, and international cooperation and efforts, are also discussed.

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It is clear that buoy vandalism has a significant financial impact to NDBC's buoy operations, including cost of the damaged/lost equipment, ship time and labor cost for repairing, retrieval, and/or redeployment, and the cost of searching for adrift buoys. More importantly, vandalism disrupts the vital data collected and reported by the buoy systems, which place lives, property, and economies in peril. Data collected by NDBC buoys contribute to saving lives, making marine operations safer, aiding commerce and transportation, and protecting the environment. Impacts of buoy vandalism are extremely significant from financial, scientific, marine prediction and warning, and marine operations standpoints. For example, since the TAO buoys are critical in the monitoring and prediction of El Niño or La Niña phenomena, loss of TAO data will substantially impact climate prediction that affects important business variables like sales, revenues, and employment in a wide range of climate-sensitive industries and sectors, including commercial fishing. Damage to the WxOP and Tsunameter buoys due to vandalism results in the similar loss of critical information for weather and marine forecasts, at-sea rescue efforts from drift modeling, and most importantly, tsunami warnings – an event that could result in significant loss of life and properties in coastal communities throughout the world.

As NDBC data buoys are located in U.S. coastal waters as well as in the open ocean, vandal activities occur to these buoys around the world (both inside and outside of U.S. EEZ). In addition, data buoy vandalism also occurs to any country in the world having moored data buoys. Therefore, preventing data buoy vandalism is not solely an effort by the U.S., but is rather an international effort.

NOAA, NDBC, countries participating in the Joint World Meteorological Organization (WMO) and Intergovernmental Oceanographic Commission (IOC) Technical Commission for Oceanography and Marine Meteorology's (JCOMM) Data Buoy Cooperation Panel (DBCP), and other buoy operators have recognized the vandalism problem for a long time. So far, this problem has mainly been addressed through education and outreach. Recently, national and international efforts to address data buoy vandalism problem have been ramped up in an effort to gain regulatory and statutory aid through international coalition.

In this paper, we present various vandalism incidents experienced by NDBC with examples encountered in NDBC's three buoy networks. The impacts of vandalism to NDBC, the scientific and marine communities, and the U.S. Government are described. This paper will also highlight recent efforts and preventive measures that NDBC, NOAA, and the international ocean community are taking to curtail acts of vandalism.

II. VANDALISM ON WEATHER AND OCEAN BUOYS

NDBC's Weather and Ocean Platforms program started in 1967 (when it was called the National Data Buoy Development Program under the control of U.S. Coast Guard). Since the program's inception 40 years ago, vandalism has been a serious problem for NDBC. Vandalism has increased dramatically over the past few years and is causing significant problems to the ocean observing network. Within the last five (5) years, the program has seen fifty-four (54) documented cases. At an average cost of $100,000 per event – that's a cost of $5.4 Million to the taxpayer and an incalculable loss when factoring in the economic impact to the US economy due to erroneous and missed forecasting opportunities.

In general, weather and ocean buoy outages and key failures are primarily attributable to the following root causes:

- Mooring failure
- Mechanical damage to superstructure
- Physical damage to electrical system components or cables (power and telemetry)
- Physical damage to critical sensors

A significant portion of these failures are related to acts of vandalism. In 2008, the overall failures and failures related to acts of vandalism of the aforementioned failure modes were documented and summarized in the following:

- Mooring Failures: Out of a total of 19 mooring failures, 8 were attributed to vandalism for a percentage of mooring failures due to vandalism (likely or confirmed mooring line cut) of 42%.
- Mechanical damage to superstructure: Three (3) of the 6 structure damages were likely result of collision or pulling on super-structure.
- Physical damage to electrical components/cables: Out of 11 failures due to electrical component damage, 3 were likely or confirmed results of vandalism.
- Physical damage to critical sensors: twenty: Two of the 24 failures due to critical sensor damage were confirmed as a result of vandalism.

Overall, there were 16 buoy failures due to vandalism (among a network of 109 buoys) in 2008. The damages or failures were mainly caused by the following vandal actions.

- Vessels colliding with buoys - Figure 2 shows the superstructure at station 42007 was clearly damaged by a vessel.
- Vessels tying up to the buoys - Figure 3 shows a technician was repairing sensors damaged by a vessel at buoy station 46006. Note the black line tied to the lower buoy structure (at the right side) was not NDBC's line and was a leave-over from a fishing or recreation vessel which make the damage to the sensors.
- Fishing vessel nets or lines entanglement and cutting of the mooring line - Figure 4 shows the retrieved mooring line (nylon line) at station 41040 was fouled with a long-line.

- Theft of the buoy system or its equipment – Figure 5 shows some sensors and a solar panel were vandalized from station 46041.

In 2008, the cost to the taxpayer for the eight (8) mooring failures (which will be discussed below) is $2,000,000. Of that, it costs NOAA/NWS nearly $800,000 to restore the observations; the remainder is the cost to the United States Coast Guard (USCG) in ship or other asset support. The overall associated program cost to NOAA for remedying all types of failures caused by outside interference is nearly $1,000,000.

After reviewing several case studies, it's fairly obvious that certain locations will continue to present a high likelihood and occurrence of vandalism. For example,

- Station 41001 (Cape Hatteras, NC): From 1979 to 2008, there were 17 mooring failures and 12 of them had high likelihood of vandalism causing failures (70%).
- Station 41002 (S. Cape Hatteras, NC): From 1982 to 2008, there were 11 mooring failures and 5 of them had high likelihood of vandalism causing failures (46%).
- Station 44005 (Gulf of Maine): From 1983 to 2008, 16 mooring failures and 7 of them had high likelihood of vandalism causing failures (44%).

One may question why NOAA continues to maintain the observations at the problem locations. The reason is that the data at these locations are of such importance to the weather service and the respective stakeholders that the cost of not having the observations are dramatically more in terms of economic and marine safety implications than the cost of taking continuous corrective actions. Of course, NDBC always investigates and works with NOAA/NWS and stakeholders to find more suitable and less problematic locations for these buoys.

Figure 2 NDBC WxOP buoy damage due to vessel collision.

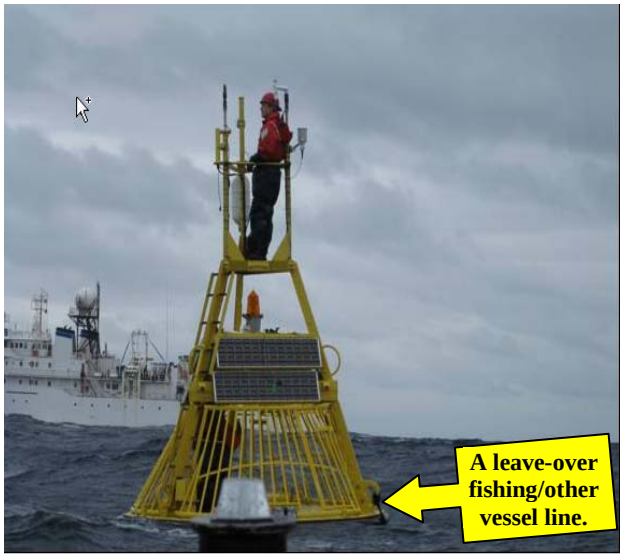

Figure 3 NDBC WxOP buoy vandalism: fishing activity

Figure 4 NDBC WxOP buoy vandalism: long-line

Figure 5 NDBC WxOP buoy vandalism: theft

III. VANDALISM ON TAO BUOYS

Vandalism has been a problematic issue for TAO since the programs inception. In recent years, specifically the last decade, the frequency of vandal occurrences has increased, resulting in noticeable impacts to the TAO programs performance (quality, schedule, and cost). For example, between October 2007 and June 2008, eighteen (18) TAO buoys in the Tropical Pacific Ocean went off-station due to vandalism. The financial cost to the U.S. Government (NOAA) for this vandalism is roughly estimated at $1 million annually. Efforts have been initiated by the TAO program to better understand the cause and affect, cost and quality performance impacts, dynamics and potential solutions to buoy vandalism.

The impacts of the vandalism problem are better quantified in two areas: (1) the U.S. government resources loss impact due to vandalism in the TAO array and (2) the product quality performance impact (TAO data availability) to the program. The quality performance metric for TAO is in terms of network data availability. The quality performance target for TAO is 80% network availability. A rough order estimate is that vandalism contributes a continuous 15% to 20% impact to product quality.

The major causes of vandalism for the TAO buoys can be attributed to:

- Vessels colliding with buoys
- Fishing vessel nets or lines entanglement
- Fish operations using the buoys as fish aggregating devices (FADs)
- Theft of the buoy system or its equipment

When a vessel hits a buoy system, it could (i) damage the buoy hull (as seen in Figure 6) so the buoy loses its buoyancy and sinks or (ii) damage the equipment or its supporting structure (as seen in Figure 7, the superstructure was severely damaged and the sensors and other equipment were all gone). When a fishing vessel's fishing gear becomes caught or tangled with a buoy's mooring system, the vessel operators typically either cut the fishing gear or cut the mooring line. When the mooring is cut, the buoy becomes adrift and data are lost or unusable. Even if the vessel operator is kind enough to cut its own gear, the related action or a large amount of fishing gear left on the mooring line could still damage the buoy/equipment (especially the underwater sensors) or degrade the data. Figure 8 shows a large amount of fishing net recovered when retrieving the TAO buoy/mooring system.

When fishing operations rely on buoys as FADs, the fishing vessels either tie off their own FADs to the buoys or tie their vessels off on the buoys and utilize a "sling shot" method to harvest a larger amount of fish. The "sling shot" method is applied in the following steps: (1) a fishing vessel ties to the buoy; (2) the vessel moves away and stretches the mooring; (3) the vessel releases the buoy; (4) the buoy settles back over the anchor while the buoy is returning to the original position; and (5) the vessel sets nets to catch the fish following the buoys. We frequently find buoys with hawsers attached to the buoys, which is an indication of a sling shot. This method places a tremendous amount of stress on the buoy mooring line and anchor system. These actions will either damage instruments and equipment or rip the buoy from its mooring and make it go adrift. Through satellite tracking of buoy movement patterns, NDBC has sufficient data to conclude that the buoys are damaged after being used in this manner. Figure 9 shows a TAO buoy being repaired by a technician. Note the thick tug line on the buoy hull was not NDBC's line but was a line used by fishermen to apply the "sling shot" method.

Figure 6 TAO buoy hull damage due to vessel collision

Figure 7 TAO buoy superstructure damage due to vessel collision

Figure 8 TAO buoy vandalism: long-line

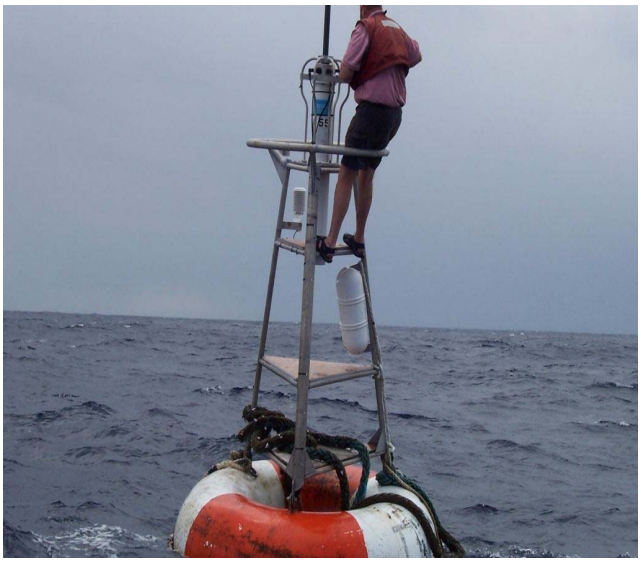

Figure 9 TAO vandalism – fishing activity (possible sling shot)

A recent case of buoy theft occurred at an NDBC TAO buoy resulting in the total loss of the asset. On May 1, 2009, the TAO mooring located at 8°N 95°W showed signs of vandalism evidenced by the simultaneous failure of all surface and subsurface instruments. Initial indications were that the buoy had been pulled from its anchor and was adrift (the equipment's Argos transmitter was still working and was providing track information). By the next day it became obvious that the equipment was on a ship as it was traveling at a high rate of speed. It made landfall at Puntarenas, Costa Rica on May 14, 2009 shortly after midnight GMT. The position of the equipment was relayed to the Costa Rican Coast Guard via the U.S. State Department on May 14. On May 15, the Costa Rican Coast Guard searched the area for the missing equipment, but was unsuccessful. The equipment stopped transmitting its position later that day, indicating that it had been taken inside or concealed.

The following table (Table 1) is an excerpt from the log of vandal activities recorded by the TAO program during May and June service cruises in 2009. Of the 21 buoys visited during this period, 9 buoys exhibited some forms of vandalism (i.e., line cut, hawsers, long liner gear, and missing equipment) resulting in 43% of the buoys being affected.

IV. VANDALISM ON TSUNAMETER BUOYS

The Tsunameter buoy network is relatively new program to NDBC. NDBC completed the 39-buoy network in March of 2008. Due to the remoteness where the buoys are positioned and the difficulty in getting vessel support for discrepancy response it has been difficult to gather conclusive data on the causes for the buoys going adrift.

The equipment and labor cost for replacement of a tsunameter buoy due to the buoy going adrift is approximately $125,000. This does not include the vessel support cost. The Tsunameter program requires commercial vessel support that typically costs $25,000 per day. Some of the more remote tsunameter

Table 1 TAO buoy vandal activities in May and June 2009

Station	Date	Items Vandalized	Cruise #
8N-155W	5/8/2009	T100 lost cuts in the Nilspin	KA-09-01
5N-155W	5/9/2009	Hawser attached to buoy wind sensor damaged	KA-09-01
2N-155W	5/11/2009	Hawser attached which cut SSC cable, cuts in the Nilspin, and T500 was lost	KA-09-01
2S-155W	5/13/2009	Large amount of long liner gear T75, T150, and T500 lost, buoy hull was flooded riding low in the water	KA-09-01
5S-170W	5/29/2009	Buoy 8NM off stations 1/3 of the tower ring was missing	KA-09-01
2S-170W	5/30/2009	Fishing gear in mooring T75 & T100 missing	KA-09-01
5N-170W	6/3/2009	Wind & Tube Damaged, marker buoy inside torrid, and fishing gear around mooring	KA-09-01
8N-180	6/7/2009	Long line gear wrapped around all sub surface sensors, T25 & T300 lost	KA-09-01
8S-180	6/26/2009	T100 & Wind sensor missing, hawser attached to buoy with a fishing float hanging off bridle	KA-09-02

Table 2 Summary of Tsunameter buoy mooring failures

2006-2008 Tsunameter Mooring Failures					
Station	**Date Failed**	**Hull**	**Depth (meters)**	**Age (days)**	**Cause**
46405	01/31/06	2.6D04	3500	563	Unknown
42408	04/01/07	2.6D33	3258	351	Unknown
21417	08/31/07	2.6D38	5516	39	Unknown
44402	11/25/07	2.6D07	4334	89	Unknown
41424	12/10/07	2.6D15	5256	622	Wear
44402	01/11/08	2.6D53	2435	2	Lost
46419	01/11/08	2.6D14	2775	537	Unknown
42408	01/23/08	2.6D31	3258	247	Cut
41420	03/20/08	2.6D13	5659	718	Unknown
21417	08/22/08	2.6D38	5510	114	Cut
41420	08/22/08	2.6D10	5659	59	Unknown
21415	09/28/08	2.6D37	4744	429	Unknown
46410	12/04/08	2.6D17	3773	861	Lost
42408	12/11/08	2.6D22	3350	115	Cut

stations may take eight to ten days in transit time. This results in a total station replacement cost of up to $375,000. Although this cost is large it may be insignificant compared to the cost of not having the station available for its mission of providing data for tsunami warnings.

Table 2 is a summary of the buoys that have gone adrift and the suspected causes for 2006 through 2009. The majority of the buoys that went adrift in 2008 have yet to be recovered.

Among the fourteen adrift buoys, we know three tsunameter buoys' mooring lines were cut. For example, the tsunameter buoy at station 42408, this buoy (2.6D22) went adrift on 12/11/08 and was recovered by the R/V Pelican on 12/18/08. There was hull paint residue on the upper mooring and the substructure was bent indicating that it experienced a vessel collision. The mooring failed in the 7/8" diameter nylon rope, 1129 meters below the surface (as shown in Figure 10). A failure analysis revealed that the rope was severed by a cutting action then abrasion lead to the subsequent failure. The photo shows the failed rope end.

In some cases, although NDBC categorizes them as unknown, it is likely that some of them were due to vandalism. For example, the tsunameter buoy at station 41420 (2.6D10) went adrift on 8/14/08 and was recovered by the NOAA Ship Nancy Foster on 5/13/09. The remaining mooring was recovered as well. The mooring parted in the ¾" nylon at about 1,000 meters depth. There were abrasion marks just above the break point. The buoy's superstructure was damaged including two welded joints and the lifting handle was significantly bent (as shown in Figure 11). This type of damage indicated that either a vessel had tied up to it or it suffered a collision.

Figure 10 Tsunameter buoy vandalism: mooring line cut

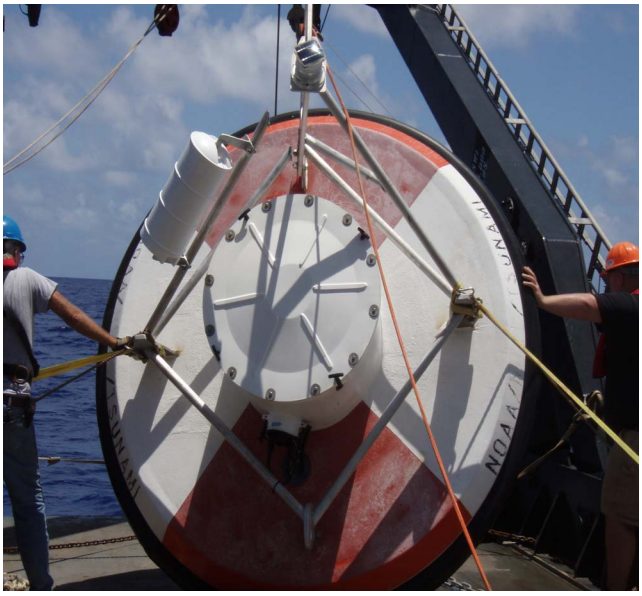

Figure 11 Tsunameter buoy vandalism: structure damage

V. PREVENTION OF VANDALISM

Data buoy vandalism has been an insidious problem for a long time. In addition to the significant financial impact to the buoy operators, impact of loss of vital ocean and environmental data from data buoys due to vandalism is huge when considering the impact to the US economy and the realized or potential loss of lives and property.

In the past years, data buoy operators around the world, such as NDBC, tried using different buoy or mooring designs to reduce or prevent buoy vandalism. These design efforts included more robust mooring systems (e.g., using abrasion or cut resistant mooring components), shorten or eliminate superstructures, protect or hide critical equipment (e.g., transmitter, antenna, etc.), make a buoy difficult to "board", and make equipment difficult to remove, etc. However, there is only so much buoy operators can do with technology and without drastically increasing operating costs. Also, it is possible that vandalism preventive designs could make a buoy system more difficult to operate and maintain, or could adversely affect the quality of the collected data. Absent of these constraints, every data buoy operator would strive to make necessary buoy/mooring design modifications to address the vandal problems.

Other than buoy and mooring design efforts, most of the efforts to prevent data buoy vandalism have been mainly limited to education and outreach. Education and outreach have limited impact on the overall problem because the underlying cause of buoy vandalism is economic in nature. It's more cost effective to the fisherman whose gear has become entangled in a buoy mooring to cut the buoy mooring than it is to cut or lose the fishing gear. It will be more effective through statutory penalty and enforcement to curtail these instances. However, education and outreach efforts have to be sustained over a long period of time can produce positive results.

NDBC will continue to investigate the prospect of disestablishing or moving buoys from problematic locations. A recent example from the WxOP program illustrates how these moves can be undertaken. A buoy located 200 nm east of Cape May, NJ was relocated 120 nm to the Northwest to reduce the effects of constant vandalism and better serve the user community. Prior to the move several discussions with stakeholders were held and it was ultimately determined that all parties would be better served by repositioning the buoy. The drawback to relocation a buoy's location is the loss of climatological measurements made at the station. NWS forecasters become dependent upon buoys being in a certain location because they can translate current measurements made at the buoy to future forecast tendencies. The loss of data at a certain location also disrupts climate records which are so important to understanding climate change

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For the U.S. domestic vandalism problem, it is suggested to review existing legal statutes and initiate modified drafts to governing authorities, if needed. King (2009) has compiled the Federal and state laws relating to data buoy vandalism. For example, Title 33 of the Unites States Code (USC) contains two statutes that can be used to prevent data buoy vandalism and accidental damage (i.e., 33 USC §408 and §412) and several statutes under Title 18 of USC may apply to the damage of data buoys. Several Parts under Title 33 of Code of Federal Regulations (CFR) contain regulations aimed at protecting aids to navigation (which is maintained and regulated by the United State Coast Guard) and could be amended to expand their protections to include data buoys. In addition, many coastal and Great Lakes states have statutes that could be used to address data buoy vandalism in state waters.

NDBC has initiated and continues to pursue coastal buoys being classified as Aids to Navigation (ATON), which would have additional regulatory, statutory and subsequent enforcement benefits. For example, there is a provision within the ATON statutes that allows for the reporter or anyone giving information leading to the conviction of a party caught damaging, destroying, or defacing and ATON, to receive up to half of the $2,500 fine. In addition to the fine, a convicted party can receive up to 1 year imprisonment. Here there is monetary incentive that is not budgeted or does not come from the operator's budget, but would be paid by the offending party. Again, it should be stressed that this is only an option for those buoys located within the boundaries of the U.S. Continental shelf. Currently, NDBC's USCG Liaison Officer has elevated the request to the USCG headquarter level and there has been preliminary legal review. However, until this is incorporated into the ATON regulatory body, the governing statutes, with respect to enforcement, are 18 USC Sec. 641 and Sec. 1361; *Public money, property, or records*, and *Government property or contracts*, respectively.

It will also be helpful to assemble a task force to investigate a data buoy vandalism alleviation strategy. NOAA plans to convene an interagency meeting with the U.S. Army Corps of Engineers, the U.S. Coast Guard, the U. S. Geological Survey, the U.S. Navy, the Environment Protection Agency, the National Park Service, and other interested parties. During a recent NOAA conference call, a plan for establishing interagency working groups was proposed. The working groups will likely be partitioned into domestic (including legislation and domestic reward program), international (including regional fisheries management organizations, other international organizations and an international reward program), and education and outreach working groups. The DBCP has been working with the WMO-IOC participants for years to highlight buoy vandalism problems. This year, the DBCP will draft a letter for the WMO-IOC that details specific issues and presents possible solutions to buoy vandalism.

To address the international vandalism problem, NOAA Office of General Counsel recently submitted a draft resolution on data buoy vandalism to the IOC (Oppenheimer, 2009; Ple, 2009), which "calls for action to the UN General Assembly in order to preserve the integrity of monitoring systems that are so essential to preserving life and property in coastal communities around the world." It has suggested to "call upon [UN] Member States to take appropriate steps under their national law to prohibit damage of or interference with ocean and coastal observing systems, institute incentives to reward those who supply information that supports enforcement of such prohibitions, develop procedures to facilitate retrieval of non-functioning ocean and coastal observing systems, and educate local communities…" It also calls upon "States and regional fisheries management organizations and arrangements, working in cooperation with other relevant organizations… to adopt conservation measures to protect ocean and coastal observing systems by 2012 and report their action to the 67th session of the UN General Assembly."

It is clear that prevention of data buoy vandalism is a difficult task. It will require a vigorous and sustained effort. However, because of the vital data provided the data buoys (which can save lives and properties), it is imperative that some immediate action be taken to reduce future losses. Now is the appropriate time to advocate and address both domestic and international efforts on data buoy vandalism.

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