Fisheries have long been an important factor when considering the economic health of a state. If left unregulated, over-fishing would threaten these valuable resources. For this reason, laws are put in place to promote sustainable fisheries. Depletion of fish stocks in certain locations can lead to illegal fishing activity, as fishermen may venture outside of their waters into foreign waters to take advantage of better fishing conditions. In these circumstances law enforcement action is necessary to deter and prevent these crimes. Smart decision-making in support of these measures will allow for more efficient and effective employment of law enforcement assets. This article will discuss how the US Coast Guard (USCG) is employing analytical techniques and innovations to support fisheries sustainment.

The USCG, the lead federal maritime law enforcement agency of the US Department of Homeland Security (DHS), is responsible for the execution of different statutory missions that assist DHS in meeting its overarching strategic homeland security goals. These goals include:

- security: protect the United States and its people, vital interests and way of life;
- resilience: foster individual, community and system robustness, adaptability and capacity for rapid recovery; and
- customs and exchange: expedite and enforce lawful trade, travel and immigration.¹

In order to meet these security goals, the USCG is exploring various analytical methods to improve efficiency, effectiveness and to establish better quantitative measures. Game theory lends itself well to these types of problems. Game theory focuses on strategic decision-making; it models cooperation and conflict in the decision-making processes of rational actors. The dynamic between an attacker and a defender can be modeled using game theory, where the decisions of one party influence the decisions made by the other. A game theoretic model has been applied in the ports, waterways and coastal security mission area in the Port Resiliency for Operational and Tactical Enforcement to Combat Terrorism (PROTECT) model. The USCG believes that game theory might be applicable to the living marine resources (LMR) and other law enforcement (OLE) mission areas, and is researching this problem for a potential future application.

By following predictable patrol schedules and conducting expected activities, law enforcement agencies leave targets susceptible to attack. The USCG decided to utilize a game theoretic model to address this concern. Game theory would allow not only for the prioritization of targets, but it also ensures that the resulting patrol schedules are randomized. Randomization still allows the USCG to employ an optimal strategy to minimize an attacker’s gain while mitigating prior observable vulnerabilities. Using game theory the USCG has created a method of conducting waterborne patrols to prevent the detection of any pattern to the frequency and duration of patrols.

Consider the following simplified scenario that demonstrates patrols under a ‘traditional’ approach as compared with a game theoretic approach. The USCG is responsible for patrolling seven distinct targets. Of these, three are of high priority (1, 2, 3), two are considered medium priority (4, 5), while the remaining two are low priority (6, 7). A traditional patrol would focus on patrolling the high and medium priority targets for a defined and consistent period of time. If two patrols are conducted each day and each patrol was scheduled to visit two high priority
targets, one medium priority target, and one low priority target, a sample patrol schedule would look like:

Patrol 1 – responsible for 1, 3, 4, 7
Patrol 2 – responsible for 2, 1, 5, 6

In this scenario, Target 1 is being visited twice as many times as the other targets. Each patrol also follows the sequential pattern of visiting high, medium, and low priority targets. If adversaries were to monitor the USCG movements, they would gain knowledge of where assets will be, how long they will be at each site, and the total length of the patrol, essentially developing a window for a possible attack.

Utilizing game theory, higher priority targets are still patrolled with a higher frequency, but there is no discernible pattern through the day or over the course of an extended period of time. For two patrols, each patrol is responsible for all seven targets. By varying the duration of each visit as well as the order of visit, each level of priority targets would be visited accordingly. For example, on average over multiple weeks, in two patrols high priority targets could be visited six times, medium priority targets four times, and low priority targets two times. However, on any given day, the actual patrolling pattern remains unpredictable. If adversaries were to monitor the movements, they would be unable to determine a fixed pattern of patrols due to the randomization of target visits as well as time on scene. This could essentially serve as a deterrent.

This example is a very basic version of the PROTECT model. PROTECT utilizes game theory to produce a patrol schedule for security patrols. These security patrols are responsible for protecting fixed critical infrastructure throughout a port. This is a relatively straightforward use of game theory for security purposes; the application becomes more complex when applied to the living marine resources (LMR) mission.

USCG Publication 3.0: Operations defines the LMR mission as a mission that “is conducted to support conservation and management of living marine resources and their environment, to include protected species, protected areas, and critical habitats. LMR mission activities include boarding of commercial fishing vessels and enforcement of LMR laws and regulations in the inland, coastal, and offshore operational areas.”

Living marine resources add difficulty to the problem due to the movement of the resources themselves. For this mission area, an adversary is targeting a particular group of resources, in this case fish, which moves based on the time of year, water temperature, food availability and many other factors. Just like fixed critical infrastructure targets, marine resources are of extreme importance. The resources that are being protected may be in danger of extinction or affected by pollution and over-fishing. While a failure to protect these resources may not lead to organizational or emotional damage for the host state, the disruption of these creatures would have other negative impacts. A species becoming extinct would drastically alter the delicate ecosystem in the ocean, resulting in an alteration to food chains that reach all the way to humans.

The first step to tackling these issues is to define the problem. The USCG deals with two primary categories of illegal fishing. The first category is fishing in closed areas, or violating the regulations imposed in established restricted areas. This category of illegal fishing is hard to model, due to the difficulty of detecting the various types of violations. For example, transiting through a restricted area with fishing gear on deck does not constitute illegal activity. On certain occasions, even fishing in a restricted area can be legal, depending on the species being fished for and the procedures followed by the fishermen.

The second category, however, is much easier to detect. This is illegal fishing in the Exclusive Economic Zone (EEZ), defined as an area encompassing all waters from the shoreline to 200 nautical miles from shore. Under the provisions promulgated by the United Nations Convention on the Law of the Sea (UNCLOS), within the EEZ the coastal state has “sovereign rights for the purpose of exploring and exploiting, conserving and managing the natural resources, whether living or non-living, of the waters superjacent to the seabed and of the seabed and its subsoil.” While the United States has not ratified UNCLOS, it does observe the customary law promulgated.
by the treaty, therefore exerting sovereign rights to the 200 nautical mile boundary line. The incursion of foreign fishing vessels into the US EEZ is easy to utilize as a starting point for model development because of the binary nature of the problem; the adversary is either within or not within the EEZ with fishing gear on deck.

The next step is to gain a thorough understanding of both the adversary and the living marine resources. In the ports, waterways and coastal security mission, we assume that adversaries are focused on surveillance of patrols and targets with an overarching goal of identifying vulnerabilities and opportunities to attack. In this case, targets are stationary, with set values of importance determined by each individual port. For living marine resources, adversaries still conduct surveillance, but the extent and methodology used varies. The targets – various species of fish – are constantly moving, and both adversaries and the USCG must calculate the probability of their being at a certain location at a particular time. To complicate the matter further, different species of fish behave and move differently, making it more difficult to predict where they will be and when.

Prior to determining patrol locations that ensure the protection of these resources, it is necessary to have some understanding of where the fish could be, and with what probability they will be in that location. Once this is determined, the problem can be approached similar to the coastal security mission. Instead of patrolling defined structures, the patrol will encompass specific sections of water for illegal fishing activity. The randomized patrol strategy resulting from a game theoretic approach would result in no detectable pattern for the illegal fishermen to exploit, making it less likely that a fisherman will attempt to fish illegally in the EEZ, closed area, or restricted area.

Another important consideration is the definition of measures of effectiveness, and how the gain resulting from employing this new strategy would be measured. One strategic goal the USCG works to achieve is an increase in maritime domain awareness (MDA). MDA is defined as “the effective understanding of those elements associated with the global maritime domain that could impact the safety, security, economy, or environment of the United States.” In the context of this problem, an increase in MDA would mean an increase in detection of illegal fishing activity or foreign fishing vessel incursions into the US EEZ. This is difficult to measure; it is impossible to detect all illegal fishing that occurs, therefore there is no firm baseline to establish whether or not an increase in sightings is actually indicative of an increase in MDA. While it is an imperfect measure, it is still one that can be utilized. Additionally, quantifying the economic risk associated with each fish stock, and expressing the economic gain resulting from successful enforcement activity, is another potential measure of effectiveness.

The ultimate goal of this research is to improve both efficiency and effectiveness of USCG patrols while minimizing risk to law enforcement personnel, the general public and the economy. The USCG has experienced resounding success through the use of game theory and randomization in the implementation of the PROTECT model, and hopes to expand the game theoretic concept not only to its mission to protect living marine resources, but to other mission areas as well. Employment of USCG assets in a sub-optimal manner is not only an inefficient use of scarce resources such as time and money, but it also increases the vulnerability of attack on the resources the USCG is tasked with protecting. By taking a smarter approach to identifying threats and decreasing vulnerability, the USCG has a chance to be a leader in the innovative use of game theory for security measures. This game theoretic approach has the potential to serve as an example for other states interested in protecting their fisheries from illegal fishing activity.

Notes
2. The Commandant of US Coast Guard, Coast Guard Publication 3.0: Operations, February 2012, p. 7.