The Decline of the Beluga Sturgeon: A Case Study about Fisheries Management

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ABSTRACT Beluga sturgeon (*Huso huso*) have inhabited the earth for more than 100 million years. During the past 20 years their numbers have declined by 90%, plummeting to the lowest population sizes ever recorded. This drastic decline has created much controversy as to whether harvest and trade of this species should continue. The situation is further complicated by management that varies among countries sharing the same resources, international trade, and altered ecological conditions that have decreased survival and natural reproduction. In January 2006, the Convention on International Trade in Endangered Species (CITES) suspended the trading of all wild beluga sturgeon caviar from the Caspian Sea. A year later, CITES re-opened the trade of beluga sturgeon, despite much pressure from researchers. Opening and closing beluga sturgeon trade impacts the market and affects many parties, including fishers, consumers, and managers. After completing this case, students will have a better understanding of the complex process of managing shared natural resources, specifically dealing with beluga sturgeon populations in the Caspian Sea region. This case will also allow students to expand their critical thinking skills for decision making on a global, ecological issue while learning about a complicated problem involving many opinions, countries, and livelihoods.

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Beluga sturgeon is a species that has been fished in the Caspian Sea since the middle 1800s (Raspopov, 1993a). This species is prized for its caviar; a kilogram of beluga sturgeon roe (or eggs) can sell on the United States market for more than US$5000. Recently, this fishery has attracted much attention due to decreasing abundance, with catches plummeting in the 1920s and continuing to decline during the past 20 years (Exhibit 1). Loss of habitat, overfishing, natural factors, and pollution have all contributed to the decline of beluga sturgeon. After the dissolution of the Soviet Union in 1991, management became more challenging as fishing rights were divided. Enforcement weakened, leading to more overfishing, poaching, and illegal trade. This case explores the issues surrounding this complicated problem and the management strategies that have been created in an attempt to protect this species from extinction.

The Case

The beluga sturgeon moved slowly through the currents of the Caspian Sea. Her sleek body was covered in prehistoric-looking bony plates, and the water quickly flowed around her as she searched for her next meal. Like all sturgeon, she used the sensitive barbels around her mouth to detect small organisms on the bottom. She stirred the sediment with her snout and felt movement. Quickly, she protruded her vacuum-like mouth into the sediment to slurp up the small crustacean buried in the mud. Most of the time, she did not feed this way. At her large size, she usually swam through the middle of the water column feeding on larger fish. However, instinct told her that she had to take advantage of every available food source. Soon she would begin her spawning migration, a trek that would cover over a 1000 kilometers and would be accompanied by long periods of starvation.

The beluga sturgeon, or great sturgeon, is the largest freshwater fish in Europe, capable of reaching lengths of 6 meters and weighing over 2000 kg (Exhibit 2, CITES, 2000; Billard and Lecointre, 2001; FishBase, 2005; Pikitch et al., 2005). During the last 100 million years, beluga sturgeon have evolved life-history characteristics that allow them to thrive in river systems that are large, diverse, and constantly changing (Beamesderfer and Farr, 1997). Delayed maturation, longevity, and high fecundity (ability to produce a high number of offspring) buffer populations from annual variation in environmental conditions (Beamesderfer and Farr, 1997). Maturing later in life allocates energy toward growth, allowing the individual to attain a larger size. This reduces predation and increases longevity (Beamesderfer and Farr, 1997). A longer life-span also allows sturgeon to spawn only during suitable years and resorb eggs during years with unsuitable conditions (Al-Holy and Rasco, 2006).

Adaptations that have allowed beluga sturgeon to thrive in naturally changing conditions are now putting this species at a disadvantage. In the past century, anthropogenic

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Abbreviations: CITES, Convention on International Trade in Endangered Species of Wild Fauna and Flora; ESA, Endangered Species Act; USFWS, United States Fish and Wildlife Service.

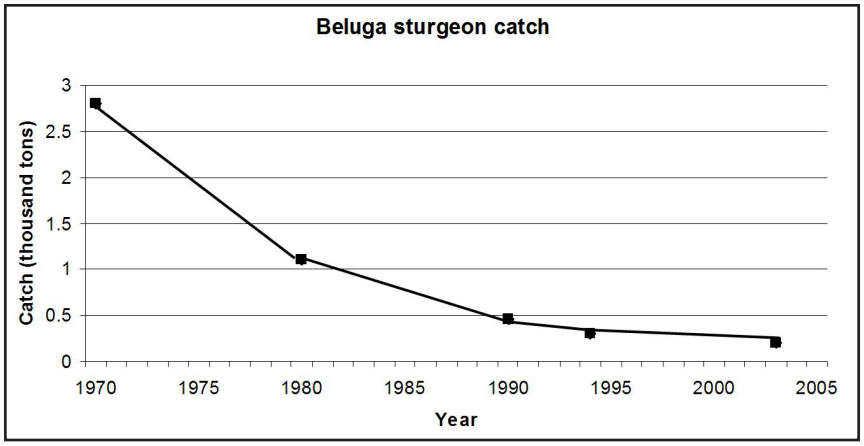

Exhibit 1. Catch data over time for beluga sturgeon, *Huso huso* (Raspopov, 1993a; CITES, 2000; Pikitch et al., 2005).

factors, such as overfishing, damming, and destruction of habitat have caused almost all sturgeon species to decrease in abundance; many of these populations have plummeted to levels where they are threatened, endangered, or even extinct (Birstein, 1993; Beamesderfer and Farr, 1997). This is especially true for the beluga sturgeon, which despite very low numbers is still heavily fished and poorly managed throughout the Caspian Sea region.

The Decline of the Fishery

Sturgeons are fished for their meat and, more commonly, their roe, which is harvested to make the expensive delicacy called caviar. Six species of sturgeon occur in the Caspian and Black Seas: the beluga, stellate (*Acipenser stellatus*), Russian (*A. gueldenstaedtii*), Persian (*A. persicus*), sterlet (*A. ruthenus*), and ship (*A. nudiventris*) sturgeon (Levin, 1997; CITES, 2000). Of these, the beluga, stellate, Russian, and Persian sturgeons supply the majority of all internationally traded caviar (Levin, 1997; Pikitch et al., 2005). With populations decreasing and fewer sturgeon available for harvest, the price of caviar has skyrocketed. Beluga caviar ranks as the most expensive of all caviars, selling for two to three times the price of other sturgeon caviar (Vaisman and Raymakers, 2001). With such a lucrative incentive, the potential reward for capturing one female sturgeon has led to heavy fishing, both legal and illegal (Exhibit 3).

> The old Russian fisherman pulled his seine net into his small boat, one handful at a time. The second fishing season of the year had just begun and he had high hopes that this season of sturgeon fishing would be better than the last. Handful after handful the net came up empty, except for a couple small chubs (*Aspius aspius*), stuck within the diamond-shaped mesh. "No luck again," he said disappointedly. He thought that due to additional regulations, the closure of fishing in the Caspian Sea, and the release of juveniles from hatcheries, his catches should be increasing. But instead, every year seemed to bring more regulations and fewer fish. The fish that he did catch were also considerably smaller than years before. And, due to increased size regulations, most of what he caught could not be harvested. Angered, he started the motor on his boat and slowly headed back to the landing, wondering where he would get the money to support his family this month.

Exhibit 2. In the past decade, fishermen have rarely seen mid-sized beluga sturgeon like the one pictured here, captured from the Volga River in Russia. Photo credit: Hans-Jurgen Burkard/Bilderberg, courtesy of Caviar Emptor.

Exhibit 3. Where the nets were teeming with fish 10 years ago, fishermen now pull out only a few small sturgeons and other fish. Photo credit: Hans-Jurgen Burkard/Bilderberg, courtesy of Caviar Emptor.

Exhibit 4. Beluga sturgeon are harvested in the Black Sea, the Sea of Azov, and the Caspian Sea. (The MapQuest logo is a registered trademark of MapQuest. Map content copyright 2007 by MapQuest. Used with permission.)

Historically, beluga sturgeon were found in the Caspian Sea, Black Sea, Adriatic Sea, Sea of Azov, and all rivers within these watersheds (Exhibit 4; CITES, 2000). Today, naturally reproducing populations are only found in the Caspian Sea and Black Sea, and a few rivers in these areas (USFWS, 2002). Populations in the Adriatic Sea are believed to be locally extinct, and populations in the Sea of Azov are composed entirely of hatchery-raised fish, with the last record of wild beluga from the 1980s (Birstein, 1993; Birstein et al., 1997; CITES, 2000).

The Caspian Sea is the largest and most important area for sturgeon fisheries. This slightly saline body of water is fed by more than 100 river systems and is bordered by the countries of Russia, Kazakhstan, Turkmenistan, Azerbaijan, and Iran (Exhibit 4). It is estimated that 90% of the world's sturgeon harvests once originated from within the Caspian Sea basin (Barannikova et al., 1995; Vaisman and Raymakers, 2001; Raymakers and Hoover, 2002). Over the past 30 years, beluga sturgeon exports have drastically decreased in this area. This has resulted in a decline in catch quotas (limits that are set to regulate how many tons of fish meat or caviar can be harvested and exported), impacting fishers, fishing companies, and consumers.

Beluga sturgeon are also harvested from the Black Sea, which is surrounded by the countries of Romania, Bulgaria, Turkey, Ukraine, Russia, and Georgia (Exhibit 4). During past years, harvests from the Black Sea have contributed little to trade, but still show trends of decreasing numbers of beluga sturgeon (Pikitch et al., 2005). Populations in the Danube River, the major river that feeds the Black Sea, have become so low in numbers that they have been listed by the International Union for the Conservation of Nature and Natural Resources (IUCN) as extirpated from the upper reaches, critically endangered in the middle reaches, and vulnerable in the lower part of the river (Hensel and Holcik, 1997; IUCN, 2000).

The beluga sturgeon felt changes in the flow and temperature of the water that told her it was time to begin her spawning migration. She joined other migrating sturgeon and began to make her way up the Volga River. She swam for over 400 km until the river seemed to stop, blocked by a giant wall. To her left she felt an increasing flow and followed her instinct to swim toward it. The water was coming from an odd-shaped structure, which seemed to head upstream. She swam up it, being led over the obstruction, and was soon in the river again. She had just swam through a fish ladder, a fish passage device built to help anadromous fish pass over dams to their natural spawning grounds. She was lucky; studies showed that few sturgeon successfully pass over dams through fish ladders. And oftentimes when they do, the dam has altered the upstream waters to conditions that are not optimal for spawning and the sturgeon resorb their eggs. Our sturgeon found seemingly suitable conditions today, and instinct led her to search for an area to lay her eggs. She would have preferred a stony bottom but, because that was not available, she laid her 190,000 eggs on the fine sediment above the dam. Although her eggs would be fertilized by males that had also made the trek, the pollution and increased sedimentation in this area would not allow for the survival of her young.

Reasons for the Decline of Beluga Sturgeon

Beluga sturgeon spend most of their lives in large bodies of brackish water, such as the Caspian Sea, the Black Sea, and Sea of Azov, where they feed on small fishes, crustaceans, and worms (CITES, 2000; Billard and Lecointre, 2001). When it is time to spawn, the anadromous sturgeon leave these brackish areas and swim upstream to freshwater rivers. In the 1950s, hydroelectric dams were built on many of these freshwater rivers, blocking sturgeon from critical spawning habitat and leading to a decrease in natural reproduction (Khodorevskaya et al., 1997). It is estimated that dams on rivers leading to the Caspian Sea have impacted 90% of beluga sturgeon breeding grounds (Barannikova et al., 1995). On some dams, fish passage devices were constructed to allow passage to spawning sites, but most attempts to engineer effective devices failed (Secor et al., 2000).

Besides blocking access to spawning habitat, dams also altered cues that trigger spawning, leading to a further decline in natural reproduction. Sturgeon use environmental conditions, such as water temperature and flow, as cues to identify ideal spawning time (Beamesderfer and Farr, 1997; Vlasenko, 1984 cited in Raspopov, 1993a). Hydroelectric dams can also alter these conditions by regulating the temperature and flow of released water. Increases in flow can also increase the amount of sediment in the water, creating unsuitable habitat for egg survival.

Natural conditions, such as the rise and fall of sea level in the Caspian Sea, have also influenced sturgeon stocks (Dumont, 1995; Khodorevskaya et al., 1995, 1997). This sea is known to follow cyclical rise and fall patterns, possibly a result of tectonic forcing and climate change (Dumont, 1995). The Caspian Sea began to fall in 1929 and dropped more than 3 meters by 1977 (Dumont, 1995; Khodorevskaya et al., 1995, 1997; Kroonenberg, 2005). This lowering in sea level caused an increase in salinity. Ecological conditions shifted and food supply was reduced, decreasing the growth of beluga sturgeon (Khodorevskaya et al., 1995, 1997).

Between 1977 and 1995, the Caspian Sea began to rise again, engulfing polluted land (Dumont, 1995). Contamination levels increased as oil lakes in Azerbaijan, a result of oil extraction and lack of maintenance, were covered by rising water (Dumont, 1995). The Kura River, feeding the Caspian Sea, collected heavy metals such as copper and molybdenum from mining and industrial areas along its bank (Dumont, 1995). The Ural River became contaminated by iron, copper, and zinc from steel mills and mining operations and fertilizers and pesticides from surrounding farms (Secor et al., 2000). Studies have shown that these pollutants, pesticides, heavy metals, and toxic chemicals led to many fish kills, including one in 1988 that resulted in thousands of tons of dead sturgeon (Dumont, 1995; Shagaeva et al., 1993). Sturgeon that were not killed by the contamination showed high levels of heavy metals and pesticides in their gonads, liver, and muscles (Khodorevskaya et al., 1997; Kajiwara et al., 2003). After 1995, the level of the Caspian Sea began to drop again, and during the past 10 years it has dropped back to pre-1977 levels. But the contaminants are now part of the Caspian Sea ecosystem.

Heavy fishing has also contributed to the decline in beluga sturgeon numbers. Life-history characteristics such as late maturation make sturgeon extremely sensitive to overfishing (Birstein et al., 1997; Billard and Lecointre, 2001). Male beluga sturgeon take 10 to 16 years to sexually mature, and females mature even later in life, at age 13 to 22 (Birstein, 1993; Billard and Lecointre, 2001). In the 1990s, spawning populations in the Volga River consisted of 11- to 18-year-old males and 17- to 21-year-old females (Levin, 1997). This suggests that although most beluga sturgeon are living until reproductive age, they are probably only able to spawn once or twice before being harvested, accelerating the negative population effects of sturgeon being harvested at younger and younger ages.

In the past, size limits have allowed fishers to harvest beluga sturgeon before they were sexually mature. It is estimated that beluga sturgeon sexually mature at a size of 160 to 200 cm (Billard and Lecointre, 2001). However, size limits throughout the range of the beluga sturgeon have been set as low as 140 to 180 cm, permitting the take of sub-adult fish that had not yet spawned (USFWS, 2002).

Another problem that contributes to the overharvesting of sturgeon is that this species shows no external sexual dimorphism, meaning that males cannot be distinguished from females without dissection. Similarity between the sexes results in many male sturgeon being mistakenly killed during attempts to harvest caviar, which even further reduces the viability of populations.

> The poachers steamed along in their fast boat, following their global positioning system (GPS) to the exact location where they had set their net. The net was not detectable from the surface because it had mid-water floats to hide it from enforcers. The five workers quickly began to pull in the net. The net felt heavy and they were excited to see the large fish in the net. Due to the low numbers of sturgeon left in the Caspian Sea, they rarely caught fish this size. A female this size could produce around 5 kilograms of caviar, which could sell for more than $5000/kilogram on the regular market. If the demand was high, caviar sold in the black market could sell for an even higher price. As they lifted her into the boat, she thrashed her tail trying to get back into the water. The poachers put her on the deck and sliced her belly open. It was empty—she had already released all of her eggs. The poachers were not having a productive night. Earlier, they had caught another sturgeon, which was also void of eggs because it was a male. The female sturgeon was thrown over the side of the boat; her meat, which could only be sold for a fraction of the price of caviar, would not provide enough money to be worth the effort. Her eggs were what they wanted and, since she had already released them, this fish had been killed for nothing.

Illegal fishing is a huge problem within the sturgeon fisheries, with an estimated 50% of world trade being illegal (USFWS, 1998). There is a high demand and great reward for catching a single sturgeon, which can produce 12% of

its weight in caviar (DeMeulenaer and Raymakers, 1996). The payoff is also high; the income of illegal fishers can be three times greater than that of a captain of a legal fishing vessel and almost 10 times greater than that of a legal fisher (Raymakers, 2002). Poaching has always occurred, but with advancements of modern technology and declining stocks, it is a much larger problem today. Technology, such as GPS and faster boats, allow poachers to easily adapt and avoid new measures of enforcement and control (Raymakers, 2002).

Illegal catch and trade of beluga sturgeon caviar is a serious issue. Illegal catch in the Caspian Sea is thought to be 6 to 10 times higher than the legal catch in this area (Speer et al., 2000; Vaisman and Raymakers, 2001; USFWS, 2004). The illegal harvest in this area is estimated to be 6,700 to 10,640 tons per year (Vaisman and Raymakers, 2001). In the Black Sea and Sea of Azov, illegal catch is even higher: 19 to 29 times more than the reported catch (Pikitch et al., 2005).

Sturgeon Management

Management of sturgeon fisheries within the Caspian Sea began in the 1950s and regulations have varied over the years (Barannikova et al., 1995; Khodorevskaya et al., 2000). A ban on sea harvest in 1962 concentrated fishing in the lower reaches of the Volga River, allowing sturgeon to feed in the Caspian Sea without harvest pressure (Barannikova et al., 1995; Khodorevskaya et al., 1997). Juveniles could reach sexual maturity, increasing the number and size of adult fish, and caviar production from individuals (Barannikova et al., 1995). Harvest from rivers leading to the Caspian Sea was also tightly regulated with catch and seasonal closures and gear restrictions (DeMeulenaer and Raymakers, 1996; Khodorevskaya et al., 2000; Secor et al., 2000).

Stocking programs were created in the 1960s to compensate for the decline in natural reproduction due to dam construction (CITES, 2000; Vaisman and Raymakers, 2001). The former Soviet Union created stocking programs to maintain spawning stocks for commercial harvests, building 10 sturgeon hatcheries on the Volga River and 5 others throughout the Caspian Basin (Secor et al., 2000; Vaisman and Raymakers, 2001). By the end of the 1980s, these hatcheries were releasing an average of 800,000 beluga sturgeon fry each year (CITES, 2000).

With the dissolution of the Soviet Union in 1991, management issues began to arise as fishing rights were divided among the newly independent countries of Azerbaijan, Kazakhstan, and the Russian Federation. Sea fishing was allowed until 1996, when the countries bordering the Caspian Sea signed an agreement prohibiting sea fishing once again (USFWS, 2002). Although many states that allow fishing in the Caspian Sea say that domestic trade is extremely regulated, not all regulations are enforced (Raymakers, 2002). Organized enforcement has been difficult due to the lack of cooperation among countries; as a result illegal harvest, large-scale poaching, and illegal trade have increased (USFWS, 2002).

Stocking programs that had been implemented also began to decrease with the dissolution of the Soviet Union. By the mid-1990s management funding dwindled, causing many hatcheries to be shutdown as the new nations tried to develop independent economies, often with differing priorities (DeMeulenaer and Raymakers, 1996; USFWS, 2002). The aging hatchery infrastructure lacked substantial support and, by 1996, only seven of the original hatcheries remained open throughout the Volga River region (Secor et al., 2000). This caused a severe decline in the number of young fish released and an inability to compensate for the lack of natural reproduction. This decrease in stocking was not only due to the lack of funds at hatcheries, but also because hatcheries could not always catch a sufficient number of broodstock for hatchery breeding (Birstein et al., 1997).

Management of the sturgeon fishery can have great economic impacts on importing and exporting countries. The closure of hatcheries in the 1990s resulted in the loss of many jobs. Decreasing sturgeon populations and increased regulations have put many fishers, fish processing plants, and export and import companies out of business (Raymakers, 2002). Other fisheries that do not even harvest beluga sturgeon may be affected by regulations as well. Restrictions have been placed on fishing methods and gears used in other fisheries to protect young sturgeon in the Caspian Sea, decreasing the catch per unit effort of these fishers (Raymakers, 2002). Reducing beluga sturgeon quotas or closing the fishery may cause a rise in unemployment levels in many fishing communities because many workers do not have the skills or experience to simply switch to another line of work.

The Decision Makers

The Caspian Sea States. Beluga sturgeon catches are managed and regulated by individual Caspian Sea countries. Most require a commercial fishing license, and some proscribe gear, catch, seasonal restrictions, and size limits to regulate catches (Vaisman and Raymakers, 2001; USFWS, 2002). Moldova and the Ukraine prohibit sturgeon fishing altogether, and Iran and Turkmenistan prohibit all private sturgeon fisheries, allowing only state-controlled monopolies (CITES, 2000; USFWS, 2002; Pikitch et al., 2005). In June 2006, Romania, one of the top beluga caviar exporters, closed its commercial fishery for the next 10 years due to concerns about decreasing population sizes (Shepherd, 2006).

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) also controls the harvest of beluga sturgeon by restricting and regulating trade. CITES was developed to monitor and regulate trade of wild animals and plants that may be at risk due to commercial exploitation. In 1998, the beluga sturgeon was listed under Appendix 2 of CITES, requiring all specimens of beluga sturgeon, including all parts and products, to be accompanied by an export permit. These permits are only issued if the specimens are legally acquired and their harvest was not detrimental to the survival of the species. If the requirements are not met, a ban on trade can be placed on the fishery (USFWS, 2002).

Through CITES, five states within the Caspian Sea basin have made commitments to develop an internationally

accepted stock assessment program and to develop an acceptable method for deriving catch and export quotas from stock monitoring data. The Commission on Aquatic Bio-resources of the Caspian Sea was created to coordinate management and monitoring of sturgeon stocks. This commission sets annual catch and export quotas for the states of Azerbaijan, Iran, Kazakhstan, Turkmenistan, and the Russian Federation.

Importing Countries. The European Union, Japan, Switzerland, and the United States dominate global trade, importing about 95% of caviar (Raymakers and Hoover, 2002). As primary importers of caviar, conservation efforts by these countries can greatly influence beluga sturgeon stocks. In December 2000, a petition was filed with the United States Fish and Wildlife Service (USFWS) to list the beluga sturgeon as an endangered species under the Endangered Species Act (ESA). After many delays and public comment periods, the beluga sturgeon was listed as threatened throughout its range. Usually this would prohibit all import of this species. However, in March 2005 the U.S. allowed trade under a special rule (Section 4d under the ESA) permitting trade with exporting countries that submitted written management plans, annual reports, and copies of national fishing laws (USFWS, 2005). The USFWS believed the conservation measures created by CITES could be effective for protecting Caspian Sea and Black Sea sturgeon if fully implemented, and that continuing to trade would motivate exporting countries to create fishery management programs (USFWS, 2005). However, exporting countries did not submit the required documentation detailing their sturgeon conservation plans, so an importation ban on sturgeon was enacted in September 2005.

Consumers. Consumer demand largely controls the market, heavily influencing the regulation of beluga sturgeon harvest and trade. When demand is high, pressure for trade and illegal fishing will increase. By educating consumers about the decline of beluga sturgeon stocks, demand may be reduced or shifted to sturgeon stocks that are more sustainable. If consumers only buy caviar from stocks that are properly managed, then Caspian Sea countries will be forced to change management strategies or they will lose business.

The Decision

Due to the decline in sturgeon populations, CITES banned international trade of all wild sturgeon caviar from the Caspian Sea basin, the Black Sea–lower Danube River basin, and the Amur River basin for 2006 (Chivers, 2006; Raloff, 2006). The only country that was allowed to export caviar was Iran, with a quota of 45,000 kg of Persian sturgeon caviar (Chivers, 2006). The suspension on trade for all other countries would be lifted in 2007 if management plans could show that harvests were sustainable (Chivers, 2006).

In January 2007, CITES set the quotas for the year. Azerbaijan, Iran, Kazakhstan, Turkmenistan, and the Russian Federation would be permitted to trade a total of 86 tons of wild sturgeon caviar in 2007 (CITES, 2007). However, the quota only allowed the trade of Russian, Persian, and stellate sturgeon species; CITES postponed the decision on beluga sturgeon trade in order to allow export countries an opportunity to provide missing information about the sustainability of beluga sturgeon catches (CITES, 2007). A month later, CITES set quotas and re-opened the trade of the beluga sturgeon for 2007 (Roberson and Crownover, 2007).

Researchers have identified reasons for the decline of the beluga sturgeon and some actions have been taken to protect remaining populations of beluga sturgeon. However, populations do not seem to be rebounding. Crucial data that are needed to create effective management plans are still lacking. Dams still block essential spawning habitat and alter sturgeon spawning cues. Illegal fishing still persists in high levels throughout the Caspian Sea. Consumers still demand caviar, driving both the legal and illegal markets. And, these are just a few of the problems that hinder beluga sturgeon populations. The road to recovery for beluga sturgeon is one of great complexity. However, if the many parties entangled in this complicated problem understand its urgency and are willing to work together, it may be possible to allow beluga sturgeon populations to successfully recover.

Teaching Note

Case Goals and Objectives

The goal of this case is to provide students with a better understanding of the difficulty of managing natural resources, specifically beluga sturgeon. After discussing this case, students will have gained a better understanding of the complicated process of managing natural resources, expanded their critical thinking skills for efficient decision making on a global ecological issue, gained experience in resolving conflict between groups (e.g., managers, fishers, consumers) with differing opinions about how natural resources should be managed, and gained an awareness of the decline of beluga sturgeon and the steps that are being taken to allow its recovery.

Uses of This Case

This case was developed to be used in biology, ecology, fisheries management, or natural resource sustainability courses. Before students read and discuss this case, the instructor may want to provide an overview of the case. Radio clips are available on the National Public Radio (NPR) website, describing the decline of beluga sturgeon in the Caspian Sea (see "Additional Resources" section). Instructors may also want to ask students to read the classic paper by G. Hardin: "Tragedy of the Commons" (see "Additional Resources" section).

After reading the case study, students can be divided up into groups and each group can be assigned a part for a role-play simulation. Group members will work together to research their particular role. Pertinent discussion points and additional references are provided for each part.

Researchers. Encourage students to research the life history characteristics of beluga sturgeon (or other sturgeon species) and discuss how these characteristics make sturgeon prone to overfishing. Have students graph the age–length relationship for beluga sturgeon. At what age

or length are beluga sturgeon sexually mature? Do current regulations allow beluga sturgeon to reproduce before they are harvested? Have students research the effect that dams have on the spawning migration of anadromous fishes. How do dams influence their spawning cues? Can anything be done to reduce negative impacts to beluga sturgeon populations? What types of restrictions and regulations should be included in a management plan to allow the recovery of beluga sturgeon? Students acting as researchers may want to reference Raspopov (1993a, 1993b), Beamesderfer and Farr (1997), Billard and Lecointre (2001) and FishBase (2007) for additional information.

Hatchery Manager. Students in this role will want to learn more about sturgeon stocking programs in the Caspian and Black Seas. Have students discuss the hatchery process, from obtaining broodstock to releasing young fish. It is thought that stocking has been effective but the contribution of hatchery-raised fish to the current population is unknown. Is there evidence that stocking programs are rebuilding sturgeon populations? How can hatchery efforts be improved? How will genetic diversity be preserved if hatcheries can only obtain a limited number of broodstock? Hatchery managers should evaluate the hatchery process and develop a plan to improve future actions. Students acting as hatchery managers may want to reference Secor et al. (2000), Billard and Lecointre (2001), and Williot et al. (2002).

Hydroelectric Power Plant Administrators. Dams on rivers flowing to the Caspian Sea supply energy to surrounding communities. However, they also can impede the movement of sturgeon to breeding grounds and alter natural spawning cues. Students will research advances in hydroelectric dams that reduce their negative effects on fishes. Can dams be modified to be ecologically friendly while still providing energy to surrounding communities? Can water be released in a way that provides conditions suitable for sturgeon spawning? Is it economical for power plants to install new advances to protect sturgeon? Students may want to search online for ways dams in the United States have reduced negative effects on anadromous fishes (including Atlantic and shortnose sturgeon). Students with the part of the power plant administrator may want to reference Billard and Lecointre (2001, p. 361) and Williot et al. (2002).

Fishers. As quotas are lowered, fishers, fish-processing plants, and export companies may go out of business. Some workers may not have the skills and experience to switch to another line of work. Create a program that will provide financial stability to fishers if quotas are lowered or the fishery is closed. Who should pay to train or compensate fishers? Do you think most fishers would be willing to stop or reduce fishing if they understood the current status of beluga sturgeon populations? How can illegal fishing be stopped? Students may want to search online for programs in the United States that have been developed to compensate workers after fishery closures and reference Raymakers (2002).

Consumers. The demand for caviar drives the legal and illegal harvest of beluga sturgeon. In many cases consumers are not aware that the product they are buying is being overfished. Do you think consumers would stop buying beluga sturgeon caviar if they were aware of the problem? What type of campaign could be developed to educate consumers about the current status of beluga sturgeon populations and alternative products to beluga sturgeon caviar? What are some alternatives to buying wild-caught beluga sturgeon caviar? What are the negative effects that these alternatives have on the environment? Students may want to search online for alternatives to sturgeon caviar (e.g., aquacultured sturgeon, paddlefish caviar) and certification programs (e.g., dolphin-safe tuna). Students playing the part of consumers may want to reference Monterey Bay Aquarium Seafood Watch (2007) and Caviar Emptor (2007).

Depending on the size of the class, other role-play parts can be added. These can include representatives from Caviar Emptor (non-profit organization), USFWS, or CITES. After each group has researched their part and talked about the discussion points, have the groups come together to share what they have learned with the entire class. A role of a "fisheries manager" can also be added to serve as a moderator as groups discuss each point of view. Students should then work to create a management plan for beluga sturgeon that all parties agree on. After this activity, students can be asked to answer the discussion questions.

Additional Resources

Hardin, G. 1968. Tragedy of the commons. Science 162(3859):1243–1248.

www.caspianenvironment.org/newsite/index.htm (verified 12 June 2007). Caspian Environment Programme.

www.caviaremptor.org (verified 12 June 2007). Caviar emptor: The decline of the Caspian Sea Sturgeon.

www.cites.org (verified 12 June 2007). Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

Radio clips from National Public Radio (www.npr.org; verified 12 June 2007):

Beluga Caviar Trade. All things considered. 15 Mar. 2002.

Nation: U.S. may ban imports of beluga caviar. 5 Dec. 2002. Morning Edition.

Environment: Caviar exports halted to protect sturgeon. 3 Sept. 2004. Morning Edition.

Discussion Questions

1. Who are the major decision makers and decision influencers in this case? Which do you think should have the most influence on how the beluga sturgeon fishery is regulated? Why? There are many decision makers that influence how beluga sturgeon populations are regulated. Countries that harvest and export beluga sturgeon have the power to regulate their own resources by enforcing catch and size limits, or by having no harvest regulations at all. Consumer demand from importing countries also plays an important part in how the beluga sturgeon fishery is regulated. These countries can refuse to import products from other countries based on their management strategies or stock status. CITES also plays a crucial role; if exporting countries do not follow regulations set by CITES, then the countries' export quotas may

be reduced. However, adhering to the CITES agreement is voluntary. Countries that have joined CITES are legally bound to the convention's regulations concerning international trade. CITES does not take the place of national laws; participating countries must create their own laws to ensure that CITES is being followed at a national level. For more information on CITES, visit the CITES website listed in the "Additional Resources" section.

2. What factors have led to the decline of beluga sturgeon stocks in the Caspian and Black Seas? Which of these factors can be controlled, and how? Students should list the factors discussed in the case study and discuss each of these factors in depth. Controlling the factors that have led to the decline of beluga sturgeon may not be as simple as one may think. For example, if dams are removed, where will surrounding communities get electricity? How can a natural event, such as the rise and fall of the Caspian Sea, be controlled? If managers lower quotas, where will fishers get their income? Now that fishing rights are divided among new countries, rules and regulations vary among states fishing the same waters. Who is responsible for keeping track of, paying for, and enforcing regulations?

3. In your opinion, what are the major problems with current management strategies? Now that students have thought about the factors that caused the decline of beluga sturgeon populations, have them research ways that decision makers are trying to counter the effects of these factors (e.g., import/export regulations, fishing regulations, stocking of young fish, fish passage devices). Many scientists think that the major problem with current management is the fishery is not being managed as a whole. Countries that harvest from the same seas have different regulations (e.g., different fishing seasons, size regulations, and catch limits) to manage the same stock.

4. Devise a management plan to allow the recovery of beluga sturgeon. Your plan may include ideas to increase natural reproduction; protect certain sizes, ages, or sexes of fish; or encourage countries to work together for consistent management within shared waters. Now that students have discussed the major decision makers, factors that resulted in the decline of the fishery, and current management strategies, they will work to develop a management plan to allow the recovery of beluga sturgeon in the Caspian Sea. Students can examine current management plans and try to improve weaknesses in these strategies. Students may develop new plans that reduce the pressure on wild stock with restrictions on fishing gears and seasons. Others may choose to increase natural reproduction by restricting harvest of immature sturgeon and improving spawning grounds. Some may increase consumer education to reduce the demand for caviar. Increasing public awareness will also put pressure on companies to stop importing and selling beluga sturgeon caviar. There are many options to creating an effective management plan for beluga sturgeon.

One important point that was not discussed in the text is the importance of long-term monitoring of management plans. Due to the long lifespan of sturgeons, management plans may take 10 to 20 years until they can be fully evaluated (Billard and Lecointre, 2001). In the case of beluga sturgeon, populations may fall dangerously below levels from which they can effectively rebound in that long time span. Because of this, management plans must be well-planned and constantly re-evaluated.

5. Do you think that a management plan will allow the recovery of beluga sturgeon? Or, should harvest and trade be banned all together? Students should discuss their management plans and discuss flaws that may prevent recovery of the population. They should realize that some ideas may not be possible due to lack of funding or cooperation between countries. This question is one that is highly debatable. According to CITES, beluga sturgeon populations are recovering. In 2002, the population estimate in the Caspian Sea was 11.6 million individuals, increasing from 7.6 million in 1998 (Pearce, 2003). However, some organizations are skeptical of these numbers, including the National Resource Defense Council, Pew Institute for Ocean Science, and SeaWeb. These three organizations compose Caviar Emptor, a campaign created to save the beluga sturgeon from extinction. When examining catch data, they found flaws in calculations (for a better understanding of the miscalculations, instructors and students may want to refer to Pearce, 2003). After re-examining the data, scientists estimated the population to less than half a million (Pearce, 2003). Many researchers do not feel as though any management plan will be able to save the beluga sturgeon from extinction. Some scientists recommend the international trade of beluga sturgeon caviar should be stopped immediately, suggesting that CITES ban all international trade of the beluga sturgeon (Speer et al., 2000).

6. The banning of beluga sturgeon harvest and/or trade will have negative consequences on some parties. If fishing is banned, where will fishers get their income? If the demand for caviar shifts to other sturgeon or paddlefish stocks, how will managers protect these fish? This question will encourage students to think about the consequences of closing the fishery. Students should discuss how a closure of the fishery will affect other parties, such as fishers and businesses that rely on the sale of beluga sturgeon caviar. In some fisheries, financial aid may come from the states to compensate for the closure of the fishery. However, some countries may not have the funds to support fishers and businesses. Without compensation, fishers may harvest other commercially fished sturgeon or fish illegally to provide income. This could shift the demand for caviar to other stocks of sturgeon that are not currently managed, leading to a rapid decline of these populations.

7. The black market (the sale of illegal products) is a serious problem for declining sturgeon populations and seems to be driven by consumer demand. How can the demand from consumers be reduced? Do you think a certification program would work in this fishery? Consumer demand may be shifted to aquacultured products or other sturgeon stocks. However, neither of these is a simple solution. Aquaculture can negatively affect the environment through pollution and disease. Shifting demand to other sturgeon stocks will increase harvest pressure and could reduce population sizes. A better approach

to reducing consumer demand can be increasing education about the current status of beluga sturgeon populations. In some markets, programs have been developed to "certify" products that are harvested from fisheries or countries that are managing their fishery for long-term sustainability. By educating the public about decreasing beluga sturgeon populations, they may be persuaded to only buy certified products.

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