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Reducing Marine Life Mortality at Tidal Power Turbines by Added Sounds, Colors and Lighting

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Abstract:-- **Although tidal energy is promoted as sustainable and clean, about 20 – 80 % of fish passing through a tidal barrage are killed. The moving turbine blades create sights and sounds, which act as warnings to fish. Fish which have not heeded the warning, are eliminated from the Darwinian struggle for survival. In comparison, dogs learn to maneuver through cars on busy city streets. This paper proposes to enhance the warning signals to marine life encouraging (scaring) them to stay away. The warnings can be both visual and auditory. Visual stimuli can be brightly colored patterned turbine blades, accompanied by flashing lights. Auditory warning signals can be clicks that fish are sensitive to. The intensity of lights and sounds should be that they are out of range to fish at a safe distance away. The precise nature of the audio-visual warnings will depend on the, visibility, turbine speed, water speed, fish sensitivity etc. The problem is not unlike using added audio-visual warnings to keep birds and bats away from wind turbines. Simple warnings are likely to greatly reduce the mortality rates of fish from the blades, and promote continued growth of of tidal energy.**

Key words:- **Tidal energy, Turbine, marine, fish, mortality,**

1. Introduction

Tidal energy is harnessed in Canada, France, Soviet Union, China, etc. Examples include the 254 MW generating station in South Korea, and 240 MW Station in France. The world's first commercial-scale and grid-connected tidal stream generator was SeaGen in Northern Ireland in 2008. Many more tidal barrages are being planned. This paper draws attention to the problem of fish being killed by turbine blades, at a time when marine life is in worldwide decline.

Although tidal energy is thought to be sustainable and environmentally friendly, turbine blades kill about 20 – 80 % of fish from impact and pressure shock [1,2,3]. More fish are mortally wounded, to die at a later time. Larger fish are more likely to be killed or injured. Fish mortality is taken to be a largely unavoidable side effect of hydroelectric and tidal power.

As marine life has been declining dramatically over the last few years and decades, it is more important than ever to explore ways to reduce their mortality at tidal energy turbines.

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A. *Wind Turbines Killing Birds and Bats*

The problem of tidal energy killing marine life is not very different from wind turbines killing birds and bats from impact and pressure shock [4,5,6]. Animal mortality may be a major reason for the declining growth and even dismantling of wind turbines in the US.

The solution proposed is to enhance the audiovisual warnings of wind turbines. More specifically, sound and flashing lights may be placed at the leading edges of the blades [7,8,9].

The solution proposed in this paper for hydroelectric turbines is not unlike for wind turbines, meaning that sound and visual warnings to marine life should be enhanced.

2. Tidal Energy

The rise and fall of the oceans from the tides cause large movements of water through narrow channels, which can be harnessed with turbines. Tidal energy can harness from the water either the (a) velocity or (b) pressure difference.

A. *Harnessing velocity*

If velocity is harnessed, the turbines are placed in open channels in rows as in wind farms, with plenty of alternative paths for the fish. Harnessing velocity works best with waters at speeds of 4 - 5.5 mph [10]. At these speeds, a 15 meter turbine can generate the same power as a 60 meter wind turbine. Tidal turbine farms are best located close to shore at depths of 20–30 meters. The turbines off the coast of Brittany are 16 m in diameter located 36 m below sea level. Larger blades may be required to harness slower moving water over a larger channel. Such turbines present the simpler case of encouraging fish to stay away from the blades, taking alternate paths instead.

B. *Pressure or Barrage Type Tidal Turbines*

If pressure difference of the water is harnessed, a turbine is placed in the link in the barrage connecting the high and low water levels. Such barrage-type facilities are in service in France, China, Soviet Union, etc. Tidal barrages which dam estuaries restrict the free movement of sea life.

Tidal barrages are not very different from conventional hydroelectric power, except that (a) the head is low (b) water moves in both directions (c) one side of the barrage confines the fish. With moving blades ahead, there is little immediate path for the fish, which may be best off waiting for another time when the blades are not moving. It may be best for the fish to stay on their side of the barrage.

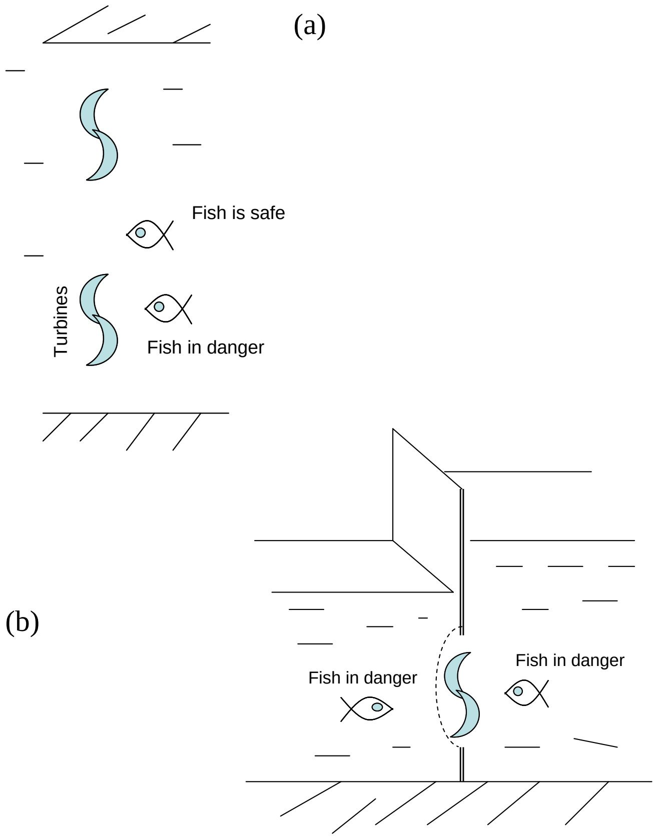

Figure 1. Turbines may either harness (a) velocity or (b) pressure. When harnessing velocity, the fish may easily take alternate paths. When harnessing pressure, the fish may best keep away or wait for a time when the turbine is not moving.

At the Nova Scotia STRAFLO facility, mortality was observed for all sizes of fish [11]. Smaller fish were less likely to be struck by the blades, but more likely to affected by pressure shear and cavitation [12]. Adult American shad had a mortality of 47 % while juvenile alosids had a mortality of 54 %.

C. *Conventional hydroelectricity*

A major environmental setback of hydroelectric dams is that they block upstream migratory paths and spawning of fish. Conventional hydroelectricity causes fish mortality not very different from tidal energy turbines with barrages harnessing pressure. The pressure difference (head) is often higher for hydroelectricity, making it difficult for fish not to be swept into the blades, once they enter or are swept into the conduits. Warning lights and sounds as suggested in this paper, can also be placed at the entrances to conduit into the turbines.

3. Fish Behavior around Turbines

Little is known about fish behavior around tidal energy turbines, but we can try to infer from the available information. .

A. *Sights and Sounds of Rotating Blades*

The moving ~15 m wide turbine blades create vibration and sound, and visual stimuli. The huge blades must be a formidable sight and the vibrations should be ominous to the fish. The vibration, sounds and sights may already act as warning to fish [13]. Fish who have not heeded the warning, are eliminated from the Darwinian struggle for survival. In case visibility is low and there is too little vibration from the fish, the fish may be getting too little warning of impending death.

B. *Observed Behavior*

In September 2010, two acoustic cameras were used to observe fish interactions with a commercial scale velocity-harnessing turbine in Cobscook Bay, Maine [14]. Twenty-two hours (nearly two tidal cycles) of footage were collected. Behaviors of individual fish and schools were classified (e.g., entering, avoiding, passing, or remaining in the wake of the turbine).

It was seen that fish were about 35 % less likely to enter turbine blades when they were not rotating. Fish were more likely to enter during the night than during the day. This difference was greater for small fish than for large fish.

Table 1. Probability of entry into turbine at Cobscook Bay, Maine

	Small fish (< 10 cm))	Large fish (> 10 cm)
Daytime	14.7 %	4.3 %
Night-time	15.3 ^%	33.3 %

Fish were almost always found in the wake of the turbine. Individual fish had a 56 % greater probability of entering the turbine than schools of fish. Individual fish would react from about 2.5 m than the 1.7 m for a school of fish.

C. *Evolutionary Needs of Fish*

From the evolutionary point of view, fish need to move from one area to another so as to propagate their genes. Fish which spread out over larger areas will have offspring thriving over larger areas. The purpose of warning fish to stay away from blades is not to stop their movement altogether, but to help them choose an alternate path if one is available. If no alternate path is available, the fish should move through the turbines as rarely as possible.

D. *The Conditioned Response*

It has been noticed that more birds die on the first day after installation of a wind turbine. Within a few days, birds “learn” to keep away from the blades. The learning process has to do with evolutionary forces, that birds and fish which do not recognize the risk of the turbine blades are eliminated.

In city areas, crows will make a commotion upon seeing an airgun. Every crow will move away, when the barrel is pointed at them. Dogs have learned to live in downtown streets, coexisting and being surrounded by cars, without being killed by them.

Faced with a man-made turbine that evolution has never taught them to avoid, fish are likely to soon learn that a close encounter with a blade can be painful or injurious. A fatal encounter may end the genetic line of fish unwise enough to avoid a blade. A fatal encounter may also teach other fish to keep away.

4. Enhanced Warning Visions and Sound

This paper proposes to enhance audio visual warnings to marine life encouraging (scaring) them to stay away. The question arises as to what kind of warning sights and sounds can be chosen. The warning depend on factors such as the (a) size of turbines (b) speed at which they are approaching the fish (c) speed of the water along which fish are moving (d) visibility of the water (e) sounds created by the turbines and their range

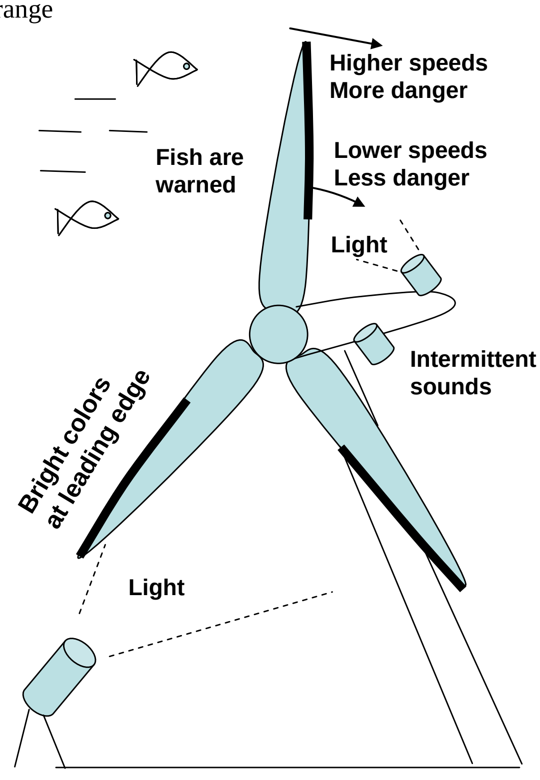

Figure 2. The outer leading edges of the blades pose the greatest risk to fish.

A Visual Stimuli

The visibility underwater may be limited, meaning that simple colors may not be sufficient warning to the fish. Bright colors are used in animal kingdom to warn other animals of danger. For marine life, the visual stimuli can be brightly colored patterned turbines, accompanied by flashing lights. A very simple step may be to shine spotlights on the turbines. The intensity and range of the lights should be just so that fish do not tire of or become accustomed to the lights when at a safe distance away.

In the case of barrage type tidal turbines, flashing bright colored lights may be placed at the conduit entrances to the turbines (figure below).

B. Auditory Stimuli

In land, sounds, such as by a rattlesnake, are used to warn animals to stay away. Marine warning sounds are less well understood but are sure to exist so as to warn other marine life to keep away. It is well known that whales, dolphins and other fish communicate with a large range of sounds.

Warning sounds may be important where the underwater visibility is poor. Warning signals can be clicks that fish are sensitive to. Otherwise, they can be the “screams” and warnings of fish in their death throes. The sounds created by predator fish can be used. As the death throes of one fish may attract bigger and predator fish, care must be used with such warning signals. Other sounds can be included according to the sensitivity of fish.

While submarines try to have the quietest possible propellers, tidal turbines can try to have the reverse objective of having the noisiest possible turbines. However the sound intensity should be just so that the fish do not tire of them, or get accustomed to them when at a safe distance away.

In case of long conduits leading to the blades, audio visual warnings may be placed at the entrance to the blades (figure below).

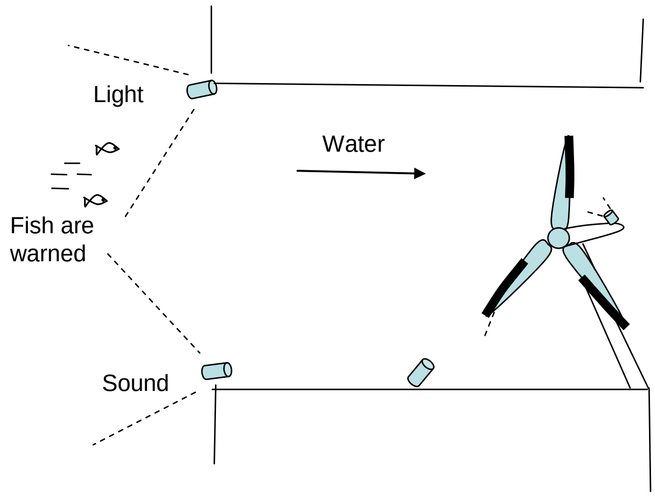

Figure 3. Audio-vidual warnings may be placed at the entrances of conduits leading to turbines.

Conclusion

Tidal energy is promoted as clean and sustainable, but mortality of marine life at the blades is a problem, in view of the worldwide decline of marine life.

Animals learn to live in dangerous environments, such as dogs learning to live on busy streets. Wind turbines kill the most birds and bats on the first day, followed by fewer fatalities on successive days. These clearly imply a learning process from conditioned responses. To supplement the learning and warning processes, enhanced audio visual warnings have been proposed at wind turbines.

Existing sounds, vibrations and vision of tidal turbines act as warnings to marine and aquatic life. This paper proposes using additional sights and sounds as warnings for fish.

The turbines harnessing free flow and velocity of water present a simpler case, as fish must just be encouraged to take alternate paths.

For barrage mounted or hydroelectric turbines, fish swimming into or swept into water conduits may find it hard to avoid the blades. For such turbines, warning lights and sounds may also be placed at the entrances to the conduits.

The enhanced stimuli can consider the size, appearance, and sounds generated by existing turbines. The visual stimuli can be brightly colored turbines and lights flashing on the blades. The auditory stimuli can be clicks fish are sensitive to or screeching that would scare fish away. The lights and sounds can be just out of range to fish at a safe distance away, so that they don't get accustomed to or used to the warnings.

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