Evaluation of Propeller Strike on Right Whale 2425 off Cumberland Island, Georgia on 10 March 2005

Necropsy Field Number: Living Animal

By

James L. Wood
Lumatrex, Inc.
P. O. Box 510129
Melbourne Beach, FL 32951
321-956-1939

Draft – April 3, 2005

Prepared for:

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Evaluation Results

Propeller Cut Series I

- Propeller Diameter – 64 cm (25 inches)
- Propeller Blades – 4
- Propeller Rotation – Counter Clockwise (CCW)
- Vessel Advance Coefficient – 1.05
- Propeller Pitch - > 27 inches

Propeller Cut Series II

- Propeller Diameter – 72 cm (28 inches) or 63 cm (25 inches)
- Propeller Blades – 4
- Propeller Rotation –Clockwise (CW)
- Vessel Advance Coefficient – 0.80 or 0.90
- Propeller Pitch - > 23 inches

Propeller Cut Series I and II Average

- Propeller Diameter – 66 cm (26 inches)
- Propeller Blades – 4
- Propeller Advance – 25 inches/rev
- Propeller Pitch - > 25inches
- Vessel Advance Coefficient – 0.92
- Vessel's Approach – from right rear of whale
- Vessel's Length – 40 to 50 feet
- Vessel's Beam – Approx. 13 feet

Known Details from Witnessed Event

Vessel

- Sabreline 42 Express Cruiser
- Length – 42' 3"
- Beam – 14' 4"
- Weight – 29,000 lbs.
- Twin Screws
- Propeller Diameter - 26 inches
- Propeller Blades – 4

- Propeller Advance – 24.5 inches/rev
- Propeller Pitch – 35 inches
- Gear Ratio – 2.227:1
- Engine Speed @ 20 Knots – 2227 rpm
- Propeller Speed @ 20 Knots – 1000 rpm
- Advance Coefficient @ 20 knots – 0.94

Right Whale 2425

- Adult
- Approximate Age – 11 years
- Fluke Width – 494 cm

Reported Accident

- Date and Time – 10 March 2005
- Strike Location – Cumberland Island, Georgia

Summary

On 13 March 2005 the author was contacted by Amy Knowlton of New England Aquarium regarding a non-fatal vessel strike on a right whale off Cumberland Island, Georgia. This is a unique incident because the operator of the vessel immediately reported the incident to authorities and provided specific details regarding the accident and the vessel to researchers involved in documenting the accident. It was suggested that this incident could serve as a blind test for evaluating methods and computational tools developed by the author for analyzing propeller cuts visible in photographs of marine mammals. The author accepted the opportunity to test these methods on photographs of propeller cuts on a living animal. Photographs of the whale were provided to the author, but specifics regarding the accident and the vessel were withheld.

The results of this evaluation indicate that the vessel that created the observed cuts was between 40 and 50 feet long. The beam was approximately 13 feet. It was determined that the vessel was equipped with twin 4 blade propellers approximately 66 cm (26 inches) in diameter with a pitch greater than 25 inches. The average advance coefficient for the two propellers was calculated to be 0.92. A series of cuts across the left fluke, identified as Cut Series I, were created by the vessel's port propeller which rotated counter clockwise. A series of cuts across the base of the peduncle, identified as Cut Series II, was created by the starboard propeller which rotated clockwise. It was determined that the vessel approached from the animal's right rear quadrant, and it appears that neither the speed of the vessel nor the speed of the whale changed significantly during the accident. A comparison of the relative advance coefficient, calculated as part of this evaluation, and the actual advance coefficient of the vessel indicates that the whale was essentially not moving at the time of the accident.

A photograph of vessel alleged to be involved in the accident was subsequently provided, and it was determined that this vessel is a Sabreline 42 Express Cruiser. It is 42 feet 3 inches long, and the beam is 14 feet 4 inches. The vessel is equipped with twin 4 blade propellers 26 inches in diameter, and if equipped with 500 hp engines, the pitch of the

propeller is 35 inches. The estimated speed of the vessel at the time of the accident is 20 knots. The advance coefficient for this vessel at 20 knots is 0.94.

Discussion

The history of this evaluation demonstrates that the proper application of the methods and computational tools employed requires that the resolution of the photographs must allow the researcher to accurately identify the end points of individual propeller cuts and to determine the size of the cuts visible in the photographs. The reliability of the calculated values hinges on these two factors. If the end points can be identified and the size of visible cuts can be determined, the results of these methods are reliable.

Initial photographs provided by New England Aquarium were digital files of high resolution images taken from a watercraft. All of the file names for these images were identified with the prefix "_DSC". These images did not include any information that would allow the size of the observed cuts to be calculated.

These images showed six propeller cuts across the dorsal surface of the left fluke of a whale visible in Figure 1. This series of cuts was identified as Cut Series I. These cuts appeared to follow a track approximately 45° to the centerline of the animal. The first four cuts, beginning at the posterior edge of the fluke, did not appear to be very deep. The fifth cut in the series was significantly longer and appeared to be deeper than the initial four. The sixth cut appeared to be severe. It began on the anterior edge of the fluke and cut through the fluke's dorsal and ventral surfaces for approximately one third of the distance from the anterior to posterior edges of the fluke. It then appeared to cut only through the dorsal surface of the fluke for an additional ten percent of that distance. The area between the fifth and sixth cuts was chaotic, and it was difficult to interpret the shapes of individual cuts in this area. The anterior third of the length of the first through the fifth cuts had a very distinct arch, and the skin along the margin of these cuts in the area of the arch was ragged. The remaining two thirds of the length of these cuts were relatively straight.

These photographs also showed a second series of cuts along the dorsal caudal ridge at the base of the peduncle. This series of cuts was identified as Cut Series II. These cuts were not well revealed, but they appeared to track along the centerline of the animal's body.

It was initially assumed that both series of cuts were created by the same vessel, and the divergent tracks of the cuts was caused by a severe folding of the fluke during the accident along a line approximately 45° to the centerline of the animal. This would allow the propeller to cut at different depths along the fold which would create a series of cuts with the centerline of the series approximately 45° to the animal's centerline while the ends of the cuts nearest the center of the fluke would be approximately parallel to the centerline.

Additional images were provided by Wildlife Trust/Georgia DNR. These images were taken from a NOAA Twin Otter aircraft. All of the file names for these images were identified with the prefix "IMG_" and ended with "crop_#_#.jpg". The author initially received files of these images that were copies of the original digital files, and they had been cropped and resized to create small file sizes which could be easily emailed. This resulted in very low resolution images that made it very difficult to identify the end points on individual cuts. Also, the only means of measuring the visible cuts was to estimate their size as a fraction of the width of the fluke, which was estimated to be 440 cm. These images also revealed a third set of propeller cuts posterior and to the right of the whale's blowhole. The images of this third set of cuts were not suitable for analysis.

The author attempted to use these images for analysis, but the results created more questions than answers. The calculated propeller diameters for the two series of cuts were very different. Cut Series I appeared to be from a propeller consistent with a vessel between 40 and 45 feet long. The cuts in Cut Series II appeared to be from a much smaller propeller. The tracks of the two series of cuts also appeared to diverge much more than initially thought. Attempts to estimate the beam of a twin propeller vessel that could have created the two series of cuts resulted in a vessel width of only seven to eight feet. A forty foot vessel with only an eight foot beam seemed very unusual. These three results lead the author to speculate that maybe the two series of cuts on the tail were created by two different vessels.

Fortunately, the Wildlife Trust/Georgia DNR was able to provide copies of the original digital files along with excellent radar altimeter data for specific requested images. These improved images allowed the author to properly identify the end points of specific cuts, and the altimeter data was used to calculate the magnification of each image and measure the size of specific cuts. This made it possible to determine that the propellers that created the two series of cuts were essentially the same size, the tracks of the proximal ends of the cuts in the two series were essentially parallel, and the estimated beam of the vessel was approximately 13 feet. These findings indicated that two series of cuts were created by the same vessel. It was also determined that the width of the whale's fluke was actually 494 cm.

The analysis of these photographs indicates that the vessel that created these cuts was between 40 and 50 feet long. It was equipped with twin, 4 blade propellers approximately 66 cm (26 inches) in diameter with a pitch greater than 25 inches. Cut Series I was created by the vessel's port propeller which rotated counter clockwise, and the advance coefficient for this propeller was calculated to be 1.05. Cut Series II was created by the starboard propeller which rotated clockwise, and the advance coefficient for this propeller, which was calculated using two different photographs, was determined to be 0.80 and 0.90, respectively. The vessel approached from the animal's right rear quadrant. The relatively even spacing of the cuts indicates that neither the speed of the vessel nor the speed of the whale changed significantly during the accident.

Propeller Cut Series I

The six cuts in Cut Series I, clearly visible in Figure 1, form a track that runs approximately 45° to the centerline of the animal, and they exhibit an unusually exaggerated arch shape at the anterior end of the cuts. There is an additional cut that is essentially perpendicular to the individual propeller cuts and transects the fourth, fifth and sixth cuts in the series. This cut was created by a free standing rudder positioned just aft of the propeller. Between the fifth and sixth cuts, the cut created by the rudder penetrated through the surface layers of tissue and allowed these layers of tissue to separate from the underlying tissue. This created a chaotic pattern in this region which makes the shapes of these cuts difficult to identify.

Locating a photograph of Cut Series I that was suitable for analysis was problematic. The aerial photographs that showed the cuts in this series from a point perpendicular to the surface of the fluke did not reveal the end points of the cuts adequately. The photographs taken from the surface vessel which did reveal the end points of the cuts were not taken perpendicular to the surface of the fluke and did not include information that would allow the magnification of the image to be calculated. This required that information from several different photographs needed to be combined to complete the analysis.

Cut #2 in Figure 2 was selected as the primary subject of the analysis. Though the camera position for this photograph is not perpendicular to the surface of the fluke, it is approximately in line with the centerline of the track of the cuts in Cut Series I. The oblique angle of the lens axis may limit the accuracy of the calculated results. The calculations performed on this series of cuts provided the following possibilities for the propeller that may have created the cuts:

Blades	**3**	**4**	**5**
Diameter (cm)	48	64	80
Diameter (in.)	19	25	32
Maximum Cut Length (cm)	36	48	60
Pitch (in.) >	20	27	33

`Table 1: Possible propeller values calculated for Cut Series I

It was also determined that this propeller was rotating counter clockwise and was probably the port propeller. The advance coefficient for this cut series was calculated to be 1.05.

Propeller Cut Series II

The cuts in Cut Series II are visible in Figure 3 and Figure 4. Both of these photographs are aerial views taken almost perpendicular to the surface of the fluke. Figure 3 is a view slightly anterior of perpendicular, and Figure 4 is a view slightly posterior of perpendicular. The resolution of these images limited the author's ability to precisely

identify end points of individual cuts, and this contributed to slight errors in the calculated results. Cuts in both figures were analyzed so that the results could be compared. Cuts #1 and #2, visible in both Figures, were used for the analysis.

The cuts in this series begin along the anterior end of the right side of the fluke and track across the base of the peduncle. The cuts were created by a propeller rotating clockwise which was probably the starboard propeller. A cut from a free standing rudder positioned behind the propeller is also clearly visible in Figure 3.

Cut #2 was selected as the primary subject of the analysis in Figure 3. The calculations performed on this series of cuts provided the following possibilities for the propeller that may have created the cuts:

Blades	**3**	**4**	**5**
Diameter (cm)	54	72	90
Diameter (in.)	21	28	35
Maximum Cut Length (cm)	40	53	67
Pitch (in.) >	17	23	28

Table 2: Possible propeller values calculated for Figure 3 of Cut Series II

It was also determined that this propeller was rotating clockwise and was probably the starboard propeller. The advance coefficient for the cut series, as viewed in this photograph, was calculated to be 0.80.

Cut #1 was selected as the primary subject of the analysis in Figure 4. The calculations performed on this series of cuts provided the following possibilities for the propeller that may have created the cuts:

Blades	**3**	**4**	**5**
Diameter (cm)	48	63	79
Diameter (in.)	19	25	31
Maximum Cut Length (cm)	35	47	59
Pitch (in.) >	17	23	28

Table 3: Possible propeller values calculated for Figure 4 of Cut Series II

It was also determined that this propeller was rotating clockwise and was probably the starboard propeller. The advance coefficient for the cut series, as viewed in this photograph, was calculated to be 0.90.

The difference in the calculated values for these two Figures very probably results from inaccuracies in locating the end points of the individual cuts.

Propeller Cut Series I and II

Figure 5 was used to confirm that the two series of cuts were created by the same vessel and to determine its approximate beam. This image shows that the proximal ends of the individual cuts track almost parallel to one another. This helps confirm that they were created by the same vessel. The distance between the centerline of the track of each series of cuts can be used to approximate the beam of the vessel. The calculated beam was about 13 feet.

Several of the photographs were used to determine that the longest cuts in these two series of cuts were between 42 and 45 cm long. The calculated maximum cut length for the 3 blade propeller is from 35 to 40 cm. This indicates that the 3 blade propeller is probably too small to create cuts of this size, so the 3 blade propeller can be eliminated from consideration.

A 4 blade propeller between 64 cm (25 inches) and 72 cm (28 inches) in diameter indicates that the vessel was probably between 40 to 50 feet in length. A 5 blade propeller between 79 cm (31 inches) and 90 cm (35 inches) in diameter indicates a vessel probably well over 60 feet in length. A 60 foot long vessel with a beam of only 13 feet would be very unusual, so the 5 blade propeller can probably be eliminated from consideration.

Therefore, it is reasonable to conclude that the vessel that created the observed cuts was between 40 and 50 feet long with a beam of 13 feet. The beam of 13 feet would indicate that the length of the vessel was probably on the low end of this range. It was equipped with twin 4 blade propellers between 64 cm (25 inches) and 72 cm (28 inches) in diameter with a pitch greater than either 58 cm (23 inches) or 69 cm (27 inches).

A more concise understanding of the propeller that created the observed cuts can be developed by averaging the calculated values for the 4 blade propeller:

Blades	**4**
Diameter (cm)	66
Diameter (in.)	26
Maximum Cut Length (cm)	49
Pitch (in.) >	25

Table 4: The average of values calculated for a 4 blade propeller that created the cuts observed in Cut Series I and II.

The calculated advance coefficients can also be averaged to yield an average advance coefficient of 0.92, relative to the surface of the whale. The even spacing of the cuts indicates that the relative speed of the vessel did not change significantly during the accident.

Vessel

Once all of the calculations for this evaluation were complete, the author was provided a photograph of the vessel alleged to be involved in the accident (Figure 7). Since the incident was still under investigation, specifics regarding the vessel were not available. All specifics presented here are based on the assumption that the vessel shown in the photograph was involved in the accident, and were developed by the author from sources not involved in the investigation. Once the investigation is complete and the related information is available, this evaluation will be modified accordingly.

The vessel shown in the photograph was identified as a Sabreline 42 Express Cruiser. The manufactures specifications for this vessel indicate that it is 42 feet 3 inches in length with a beam of 14 feet 4 inches. It is normally equipped with twin 4 blade 26 inch diameter propellers and with either 450 hp Cat engines with a 2.000:1 gear ratio and propellers with 31 inch pitch or 500 hp Yanmar engines with a 2.227:1 gear ratio and propellers with 35 inch pitch.

The manufacture also provides tables of performance data for vessels equipped with both engines. This data was used to prepare charts for translating values calculated from the propeller cuts into vessel operation values. For convenience, only charts for the 500 hp engines are reproduced here. The chart in Figure 8 uses the average cut span of 6.1 inches to determine that the vessel was probably traveling at just over 20 knots with a propeller speed of 1010 rpm (2250 engine rpm). The chart in Figure 9 uses the advance coefficient of 0.92 to determine that the vessel was probably traveling at just under 20 knots with a propeller speed of 990 rpm (2205 engine rpm). These values were averaged to a vessel speed of 20 knots with a propeller speed of 1000 rpm (2227 engine rpm). In the chart in Figure 10 uses the averaged vessel speed of 20 knots to determine that the propeller slip was about 30%, and the propeller advance was 24.5 inches per revolution. The advance coefficient calculated from the averaged vessel operation values is 0.94.

If the vessel was equipped with the 450 hp engines, the calculated vessel operation values would be an average vessel speed of 23 knots with a propeller speed of 1150 rpm (2300 engine rpm). The corresponding propeller slip would be about 22% and the propeller advance would be 24.2 inches per revolution. The advance coefficient calculated from the averaged vessel operation values would also be 0.94.

Conclusions

The calculations used in this evaluation indicate that the vessel that struck this whale was 40 to 50 feet in length with a beam of approximately 13 feet. It was equipped with twin 4 blade propellers 66 cm (26 inches) in diameter with a propeller advance of 25 inches per revolution and a propeller pitch greater than 25 inches. The calculated relative advance coefficient at the time of the accident was 0.92. The vessel approached from the whale's right rear quadrant. The even spacing of the cuts in both series of cuts indicates that the speed of the vessel and the speed of the whale did not change significantly during the

accident. It appears that the whale lifted the left side of its fluke into the path of the vessel's port propeller.

The calculated values correspond very closely with the known dimensions of the vessel involved. This vessel is 42 feet 3 inches in length. The beam is 14 feet 4 inches. It is equipped with twin 4 blade propellers 26 inches in diameter, and if equipped with a 500 hp engines, the propeller pitch is 35 inches. It was determined that, if equipped with the 500 hp engines, the vessel was probably traveling at 20 knots, which corresponds to an advance coefficient of 0.94.

Figure 1: Cut Series I runs across the dorsal surface of the left fluke about 45° to the centerline of the animal's body.

Figure 2: A view of Cut Series I viewed at an oblique angle to the surface of the fluke. Cut #2 is the primary focus of analysis using this image.

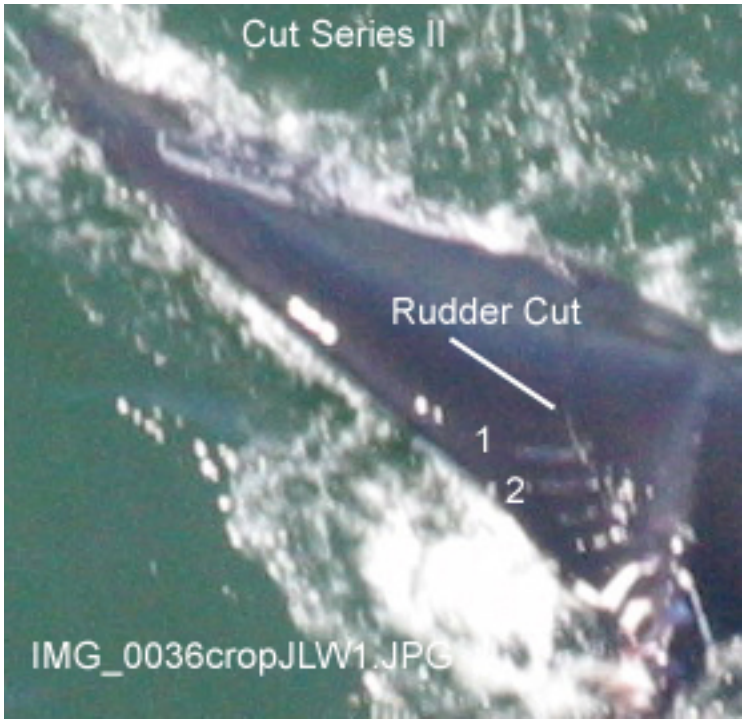

Figure 3: A view of Cut Series II from slightly anterior of perpendicular. Cut #2 is the primary focus of the analysis using this image. The limited resolution made it difficult to accurately identify the end points of the cuts.

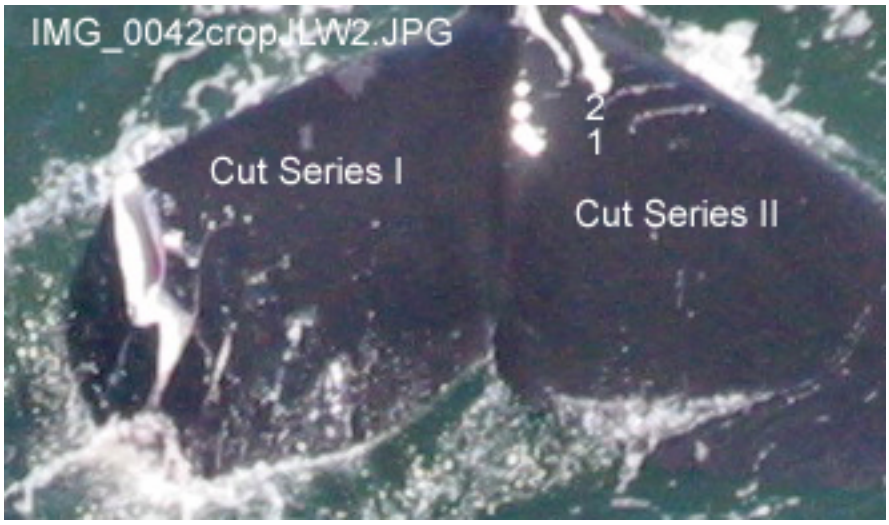

Figure 4: A view of Cut Series II from slightly posterior of perpendicular. Cut #1 is the primary focus of the analysis using this image. The limited resolution made it difficult to accurately identify the end points of the cuts.

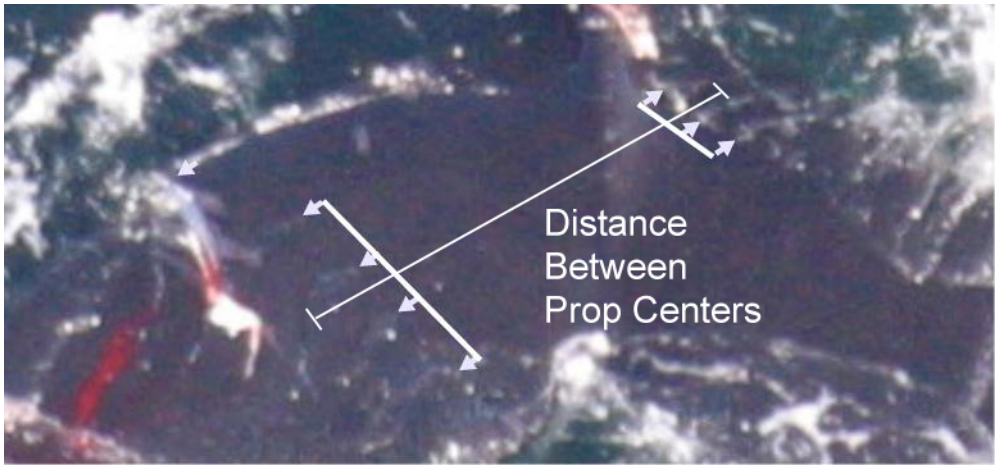

Figure 5: Cut Series I and II are both visible in this image. The proximal end of several cuts can be identified, and they appear to run essentially parallel with one another. This indicates that the two cuts were probably created by the same vessel. The distance between the centerlines of the two series of cuts can be used to estimate the beam of the vessel.

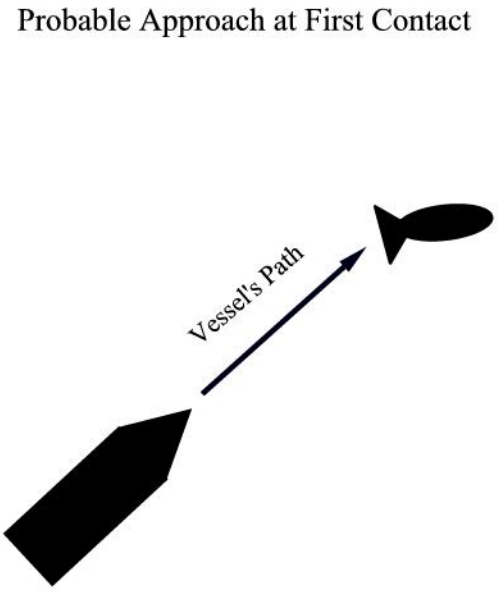

Figure 6: The vessel approached from the whale's right rear quadrant.

Figure 7: The vessel alleged to be involved in the accident.

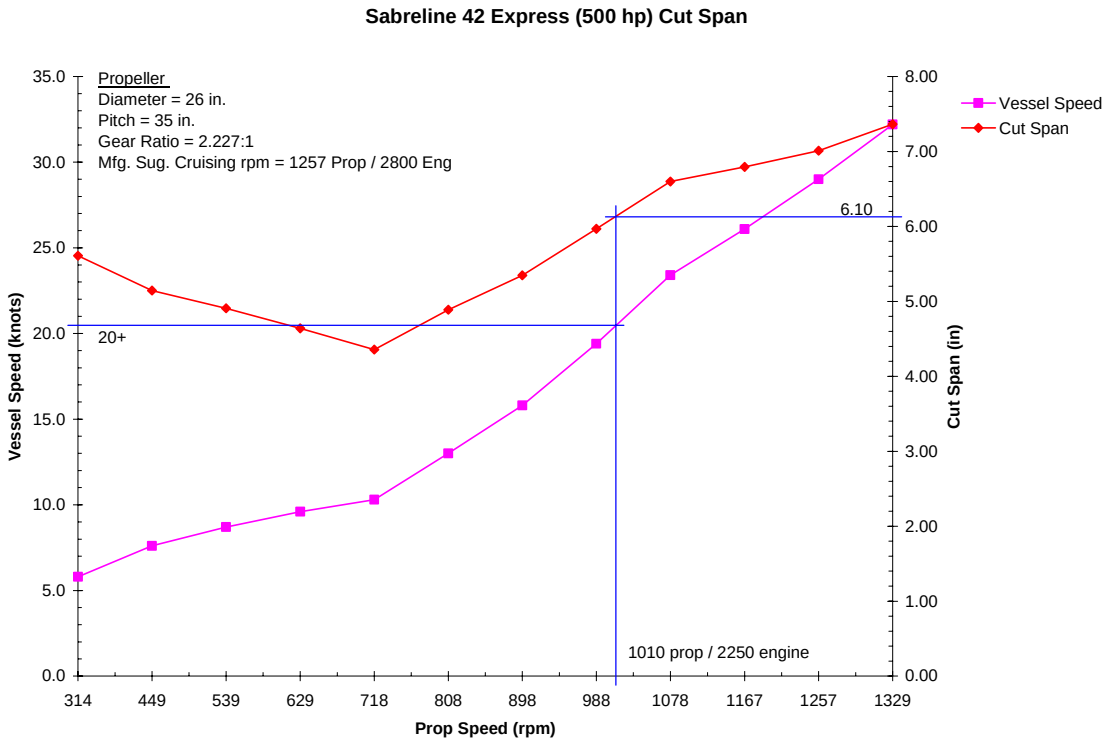

Figure 8: The average cut span of 6.10 inches indicates that the vessel, equipped with a 500 hp engine, would be traveling at slightly over 20 knots with a propeller speed of 1010 rpm (2250 engine rpm).

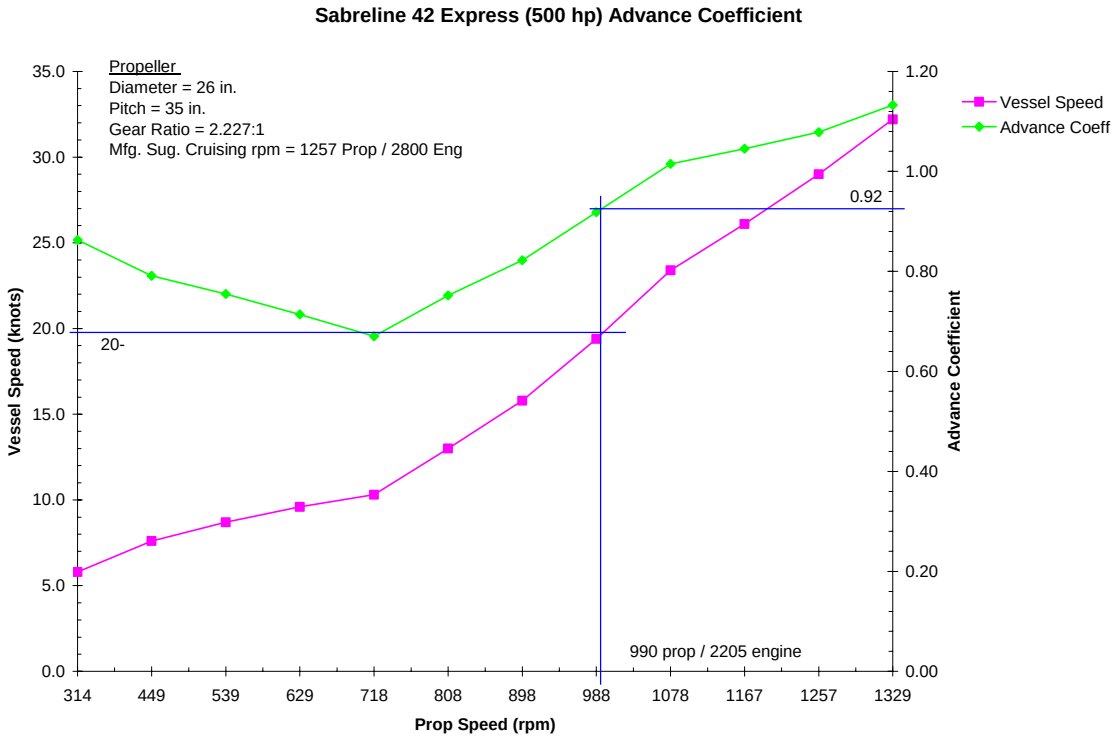

Figure 9: The advance coefficient of 0.92 indicates that the vessel, equipped with a 500 hp engine, would be traveling at slightly under 20 knots with a propeller speed of 990 rpm (2205 engine rpm).

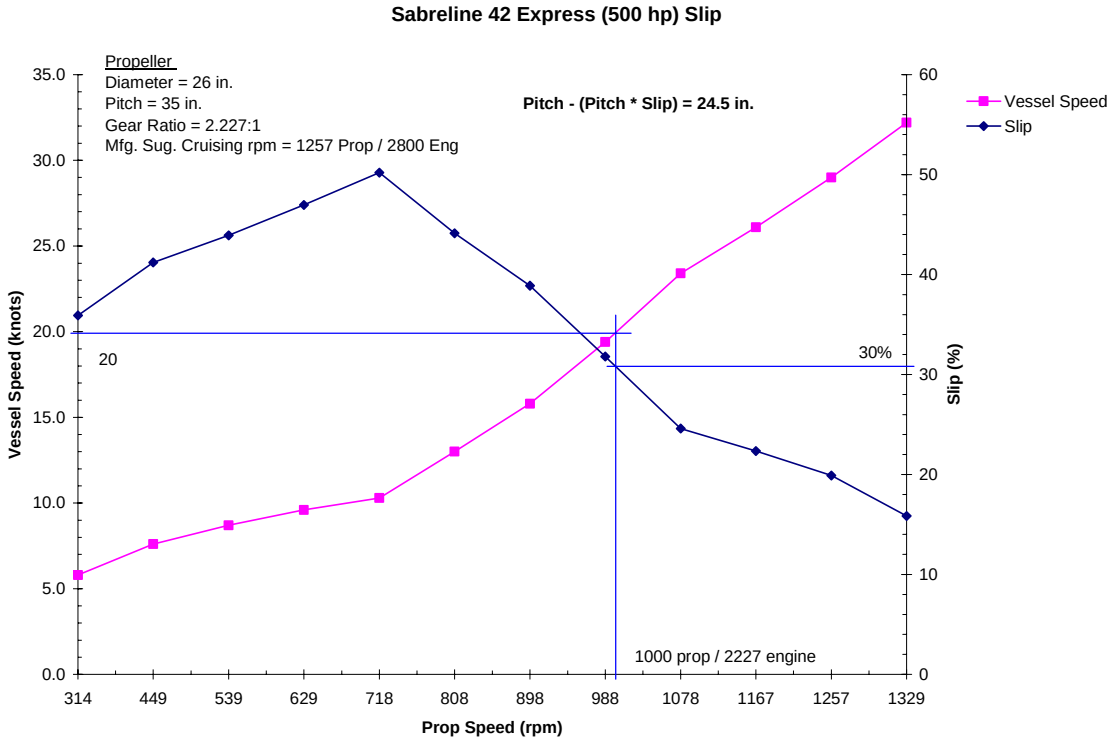

Figure 10: The speed of 20 knots indicates that the vessel, equipped with a 500 hp engine, would be operating with about 30% slip, and the propeller would advance 24.5 inches per revolution.

Acknowledgments

Photographs from surface vessel were provided by Amy Knowlton of New England Aquarium

Photographs from a NOAA Twin Otter aircraft were provided by Wildlife Trust/Georgia DNR.

Prepared By

James L. Wood
Lumatrex, Inc.
P. O. Box 510129
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jlwood@lumatrex.com